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THE CORRELATION AND RECONSTRUCTION OF RECESSIONAL ICE BORDERS IN BERKSHIRE COUNTY, MASSACHUSETTS.[1]

PRELIMINARY STATEMENT.

THE studies which form the basis of this paper were made chiefly in connection with the mapping of the surficial geology of the Housatonic quadrangle, which comprises the southern two-thirds of Berkshire county and lies mainly in western Massachusetts, but partly also in New York and Connecticut. The southern half of the Taconic quadrangle, comprising the northern third of Berkshire county and an equal area in New York, is also included. This presentation of some of the results is offered by permission of Professor T. C. Chamberlin, under whose direction the studies were made.

One of the most important things brought out by the study of this area relates to the retreat of the ice-sheet, or, rather, to the retreat of its frontal edge or margin, across Berkshire county. As is well known from the extensive studies of Chamberlin,[2] Leverett,[3] and others in the states west of New York, the retreat

[1] An abstract of this paper was presented before Section E of the A. A. A. S. at Washington, January 2, 1903.

[2] T. C. CHAMBERLIN, "Preliminary Paper on the Terminal Moraine of the Second Glacial Epoch," *Third Ann. Rep. U. S. Geol. Surv.*, 1883.

[3] FRANK LEVERETT, "The Illinois Glacial Lobe," Monograph XXXVIII, *U. S. Geol. Surv.*, 1899.

of the ice-front in that region was not by an even, steady movement giving a uniform rate of recession, but by oscillations in which there were many alternating episodes of relatively rapid retreat and less marked readvance separated by times of halting, when the ice-front remained for some time in a stationary state. These minor oscillations with repeated haltings characterized the whole of the main movement of retreat of the last ice-sheet in the West. Each halt was the occasion of the building of a frontal or marginal moraine, and the drift of the Wisconsin epoch is nearly everywhere marked by a numerous series of these *recessional* moraines.

HISTORICAL.

In the East the ice-sheet was long thought to have had a different habit, and to have made no recessional moraines like those of the West. The two great marginal moraines extending westward along the coast from Cape Cod and Nantucket Island, and converging toward the west end of Long Island, have been known for many years.[1] The extension of one of these as the so-called "terminal moraine" of H. Carvill Lewis, having a general course west-northwest across New Jersey and Pennsylvania, is also well known.[2] These, however, are not recessional moraines, but the frontal deposits of the grand climax, when the ice-front rested after the general advance and before the general retreat.

Leverett has mapped the recessional moraines of the extreme western portion of New York and of the northwestern part of Pennsylvania, and he has also mapped in detail the morainic deposits of the Olean and Salamanca quadrangles in western New York. The folios to which these belong have not yet been published, but a map of the Olean quadrangle has been issued

[1] WARREN UPHAM, "Terminal Moraines of the North American Ice Sheet," *Am. Jour. Sci.*, III, Vol. XVIII (1879), pp. 81–92, 197–209.

[2] GEORGE H. COOK, "On the Southern Limit of the Last Glacial Drift Across New Jersey and the Adjacent Parts of New York and Pennsylvania," *Am. Inst. Min. Eng. Trans.*, Vol. VI (1879), pp. 467–520; H. CARVILL LEWIS, "Report on Terminal Moraine Across Pennsylvania and Western New York," *Second Geol. Surv. of Penn., Rept. Z.*, 1884.

as a pocket map with Leverett's second monograph.[1] With these exceptions, the recessional moraines of Pennsylvania and New York have been recognized in only a few places and in short and scattered fragments. Salisbury has mapped a few fragments of recessional moraines which cross northern New Jersey.[2]

Essentially the same statement applies to New England. Emerson has identified a number of positions of the ice-front in central Massachusetts in places where it served as the retaining barrier for temporary glacial lakes or for the building of terraces of sand and gravel.[3] Woodworth has mapped two recessional halts on the western end of Long Island back of the great terminal moraine, and has made out the position of several consecutive ice-fronts by sand plains in the vicinity of Narragansett Bay.[4] Grabau has done the same in southeastern Massachusetts in the study of Lake Bouvé.[5] Crosby has found one or two morainic fragments and the positions of several ice barriers for lakes in northeastern Massachusetts.[6]

While these observations have added much to our knowledge, no considerable consecutive series of halts has been made out through them, nor has the course of the ice-front at any particular halt been traced continuously across the country for scores

[1] FRANK LEVERETT, "Glacial Formations and Drainage Features of the Erie and Ohio Basins," Monograph XLI, *U. S. Geol. Surv.*, 1902.

[2] R. D. SALISBURY, "Glacial Geology," *Geol. Surv. of New Jersey*, Vol. V (1902); also, "Pleistocene Formations," *New York City Folio, U. S. Geol. Surv.*, Folio No. 83, 1902.

[3] B. K. EMERSON, "Pleistocene," *Holyoke Folio, U. S. Geol. Surv.*, Folio No. 50, 1898; also, "Geology of Old Hampshire County, Massachusetts," Monograph XXIX, *U. S. Geol. Surv.*, 1900; also, "Geology of Eastern Berkshire County, Massachusetts," *U. S. Geol. Surv.*, Bull. No. 159, 1899.

[4] J. B. WOODWORTH, "The Retreat of the Ice Sheet in the Narragansett Bay Region," *Am. Geol.*, Vol. XVIII (1896), pp. 150–68; also, "Pleistocene Geology of Portions of Nassau of Queens County and Borough," *N. Y. State Mus. Bull.* No. 48, 1901.

[5] A. W. GRABAU, "Lake Bouvé, an Extinct Glacial Lake in the Southern Part of the Boston Basin," *Boston Soc. Nat. Hist., Occ. Papers*, Vol. IV, Part 3 (1900), pp. 601–94.

[6] W. O. CROSBY, "Geological History of the Nashua Valley during the Tertiary and Quaternary Periods," *Tech. Quart.*, Vol. XII (1899), pp. 288–324.

of miles, as is common in the West. Indeed, few if any have been traced as far as ten miles. Nor has any method of correlating the moraine fragments been worked out by which the individual ice borders may be plausibly reconstructed across the rugged country of New England. Because a distinct series of recessional moraines has not thus far been found in the East, the impression has prevailed in some minds that the ice-sheet may not have had the oscillations and halts that it did in the West. But this opinion has been held in spite of the suggestive significance of the fragmentary evidences just mentioned. The recent studies in Berkshire county have disclosed the fact that, at least within its boundaries, and in much of the country contiguous to it, the recessional halts did take place with usual regularity, and that fragmentary moraines were built along the several lines on which the ice-front rested. It is more the object of the present paper to show in particular what results bearing on the manner of the retreat of the ice-front have been attained by these studies.

TOPOGRAPHY.

The topography of Berkshire county is a rugged and varied one. The development of the present relief and its drainage systems has been almost entirely the work of subaërial agencies. Rain and frost and streams like those now there have done the work. Glacial erosion has been very slight. The development of the relief has followed the distribution of the harder and softer rocks, and lines of weakness in the former. The harder members are the mountains and uplands of today, while the valleys follow mainly the lines of the softer strata. The quartzite and gneiss of the Green mountain range, the various gneisses of Hoosic mountain and the plateau to the south, the Berkshire and Greylock schists of Greylock mountain, and the Berkshire schist of Mount Washington and the Taconic range constitute the principal areas of the harder rocks, and they are all areas of high relief, while the Stockbridge limestone and a few other less extensive, but relatively soft, strata lie chiefly in the valleys, and have determined their place and extent.

Although the Berkshires are a mountainous region the

mountains are relatively small and low. The extremes of relief range from about 565 feet above sea level on the Hoosic river north of Williamstown, and about 650 feet on the Housatonic river below Ashley Falls, to 3,505 feet on Greylock mountain and 2,624 feet on Mount Everett, otherwise known as the Dome of Mount Washington. The two principal rivers are the Housatonic, flowing south, and the Hoosic, flowing north and northwest. Their valleys are the principal valleys of the county and are united as one trough across a col about three miles northeast of Pittsfield. The altitude of this col is about 1,120 feet above tide. Some of the main sources of the Hoosic are near the col, but the Housatonic, coming from the east, receives branches of some size from the north and west near Pittsfield. The extensive area of Stockbridge limestone stretching south from the vicinity of Pontoosuc lake three miles north of Pittsfield gives rise to the broadest valley of the county. Its usual breadth is from four to six or seven miles, but for twenty miles south-southwest of Pittsfield it is broken by isolated faulted mountains, and between these from Glendale to Housatonic the river flows through a narrow gorge-like valley.

Mount Washington, which is the highest point of the southern Berkshires, rises in considerable part above 2,000 feet. Excepting this, the higher lands in the southern and southeastern Berkshires commonly reach an altitude but little above 1,600 to 1,800 feet. The plateau of the southeastern part, however, is trenched by the deep, narrow valleys of the Westfield and Farmington rivers and their branches.

In the northern third of the county the reliefs become greater. Excepting in the vicinity of Williamstown, the Hoosic valley is seldom more than a mile wide in its lower levels. South of Williamstown a considerable area of limestone develops a broader lowland along Green river, and where this merges with the Hoosic valley it has the effect of broadening the latter.

The mountain masses bounding the Hoosic valley are considerably higher than those to the south. A large part of the Greylock mass rises above 2,000 feet, as does also the main crest of Hoosac mountain, East mountain, the Taconic range, and the

southern end of the Green mountain range. In these ranges heights of 2,400 to 2,600 feet are quite common.

GENERAL ICE MOVEMENTS.

From their studies of striæ and bowlder transportation the earlier geologists, E. Hitchcock,[1] L. Agassiz,[2] and others, found that the ice-sheet moved across Berkshire county in a southeasterly direction, along the Hudson river in a southerly direction, and on the slope west of the river in a southwesterly direction, showing thus a wide southward spreading of the ice from the axis of the Hudson valley. This spreading of striæ characterizes the valley through its whole length from south to north. Such an arrangement of striæ shows that the valley was occupied at all stages of retreat by a great glacier lobe which projected far south from the general line of the ice-front and spread away laterally over the country both to the east and west of the river. Berkshire county was therefore overrun by ice from the Hudson valley lobe and may be said to lie within the territory of its retreating eastern limb. The recent studies fully confirm this conclusion from other evidences also, such as the alinement of drumlin axes, the position of stoss-side smoothing of the hills, and still more and with independent conclusiveness from recessional moraines and border drainage. It is found that in retreating from southeast to northwest diagonally across the county the ice-front halted fourteen times; that is to say, the east limb of the Hudson lobe oscillated or wavered that many times in retreating about fifty miles.

[1] E. Hitchcock, "On a Singular Case of the Dispersion of Blocks of Stone at the Drift Period in Berkshire County, Massachusetts," *Am. Jour. Sci.*, Vol. XLVII (1844); and Vol. XLIX (1845); also, "Illustrations of Surface Geology," *Smithsonian Contrib.*, Vol. IX (1857, and second edition, Amherst, 1860.) C. H. Hitchcock, "On the Marks of Ancient Glaciers on the Green Mountain Range in Massachusetts and Vermont," *A. A. A. S., Proc.*, Vol. XIII (1860), pp. 329–35.

[2] L. Agassiz, "Glacial Scratches in Berkshire and Wachusett Ranges, Massachusetts," and "Observations on a Set of Bowlders in Berkshire County, Massachusetts," *Boston Soc. Nat. Hist. Proc.* Vol. XIV (1872). Other early papers on the Richmond bowlder trains are by H. D. and W. B. Rogers, *Boston Soc. Nat. Hist.*, Vol. V (1847), pp. 310–30, and by E. Desor, *ibid.*, Vol. II (1848). But the most exhaustive paper is by E. R. Benton, *Harvard Mus. Comp. Zool. Bull.*, Vol. V (1878).

GENERAL RELATIONS OF THE RETREATING ICE-FRONT TO THE LARGER LAND RELIEFS.

It is interesting to note the general relations of the larger features of the land relief to the receding ice-front; for, according as the ice-front retreated across them in one direction or another, the recessional history of the region was one thing or another very different thing. The earlier investigators found that the general direction of ice-movement was about S. 30° to 40° E. It is a general principle that the direction of ice-movement at any point near the ice-front is about normal to the margin, so that in this case the general trend of the ice-border was presumably northeast and southwest, and remained so during its retreat across the county.

The southeastern part of the county is occupied by the high plateau already referred to. While the ice front was retreating across this area, the Westfield and Farmington rivers drained the waters freely away from the ice-front. But when the retreat had reached the western edge of the plateau, the ice-sheet obstructed the drainage of several relatively small valleys and caused the formation of temporary lakes. When it rested in the Housatonic valley, the ice-front had free drainage to the south in every position but one. From the bend south of East Lee to that west of Glendale the river flows west. During one of its halts the ice obstructed the passage at Glendale, so that the valley to the east was occupied by a lake of considerable size. West of the Taconic range in Canaan and New Lebanon in New York, more lakes were produced at a later stage in the westwardly draining valleys of that region.

But the largest lake in the Berkshires was that which was held in the Hoosic valley. The Hoosic river flows north as far as North Adams, and thence west and northwest. Throughout its whole course in Massachusetts and Vermont, and for some distance in New York, the retreating ice-sheet obstructed the normal direction of flow. The consequence was that this valley with its principal branches — the valleys of Green river and the Little Hoosic — was filled first with independent lakes, which later merged into one long, irregularly shaped body that

filled the whole valley up to the contour of about 1,110 or 1,120 feet, according as one or another of two outlets was active. Geographical considerations, which ought to control wherever possible, would suggest Lake Hoosic as the most appropriate name for this body of water. Professor T. Nelson Dale, who has described certain features which he attributes to this lake, has called it Lake Bascom in published notices. But I shall use the geographical name as being decidedly better. One of the effects of Lake Hoosic was to obliterate and render unrecognizable the deposits of the ice-front where its halts rested in the northern, deeper part. This greatly increased the difficulty of distinguishing the successive halts in that part of the area.

If the ice-front had retreated from northwest to southeast, instead of in the opposite direction, the Hoosic would have been the valley of free drainage with valley trains of gravel, and the Housatonic, Westfield, and Farmington valleys would have had the lakes with deltas. The fact that, excepting in one small part where there are deltas, the Housatonic has only valley trains, and that the Westfield and Farmington have the same, while the Hoosic valley has deltas and lake clays, but no valley trains, accords well with the evidence of striæ and bowlder transportation, showing that the ice-front did in fact retreat in a general direction from southeast to northwest.

EVIDENCES BY WHICH THE RECESSIONAL HALTING PLACES OF THE ICE-FRONT WERE DETERMINED.

While the general retreat was going on across this region, the ice-front halted many times and formed a series of recessional moraines corresponding in a general way with the recessional moraines of the Great-Lake lobes in the West, except that they are very fragmentary and relatively faint and slender. The successive individuals are also on the average more closely spaced, the average interval between the halts in Berkshire county being about three and one-half miles, and they are all intensely sinuous in their courses.

There are, however, other classes of deposits which assist very materially in determining the place of the ice-border.

Besides (1) the moraines just mentioned, which are purely ice-laid sediments, there are (2) kames, eskers, and the like, which were made by the joint action of the ice and running water, and which may generally be relied upon as good supplementary evidence; and (3) eroded river channels along the border of the ice, outwash gravel fans, valley gravel trains, deltas, etc.

Excepting for the small isolated kames which occur in sporadic fashion, kames, and especially kame clusters, are essentially ice-border phenomena and are substantially equivalent to marginal morainic deposits. They nearly always occur at or very near the margin of the ice and are very commonly associated with moraines.

Eskers are not quite so closely related to the ice-front, and yet they are generally valuable aids; for, although they may extend for miles back, they nearly always take on a characteristic modification of development where they emerge from the ice. At such places they often take the form of a small kame cluster or delta, or sometimes an outwash fan. When an esker persists during several recessional halts, it generally shows one or another of these modifications at each place where the ice-front halted, although its ridge may be typically developed in the intervals. A good example of this sort may be seen in the great esker which runs south from North Adams to Berkshire.

Deposits of the third class often show the place of the ice-front in situations where there are no contiguous recognizable morainic deposits. In the Berkshires especially this class of evidence has been invaluable. Eroded river beds along the border of the ice are traceable for long distances only where the ice-front rested against a long unbroken mountain flank, as of the Green mountain range or of Hoosac mountain. But there are many places where shorter fragments of river beds are well developed. The streams that made them were not large, as a rule, but they are often very clearly cut in situations where their occurrence would be altogether impossible without the immediate presence of the ice-front to serve as one of the retaining banks. These fragments often occur on hillsides and steep valley slopes, and in other situations where the morainic deposits are absent or

are so lacking in the usual characters of moraines as to be not surely recognized when taken by themselves. The occurrence of an old river bed at the upper limit of a hillside belt of bowldery till which has no particular morainic expression makes a combination as surely indicative of the presence of the ice-border as if it were a well-developed moraine. One of the most remarkable river beds of this kind runs along the flank of Dry hill between Hartsville and New Marlboro.

Outwash gravel fans also occur occasionally in such a way as to mark the place of the ice-front where no certain morainic deposits are discoverable. A small deposit of this kind in front of a faint moraine occurs near the base of Mount Washington west of Sheffield.

There are several moraine-headed gravel trains in the Housatonic and other freely drained valleys. These show the halting places of the ice-front quite clearly and may be safely relied upon. The gravel trains which head at Housatonic and at State Line and at Pittsfield are good examples.

Deltas occurring in association with moraines, and sometimes also with kames, are also valuable adjuncts to interpretation. The magnificent terrace at Lenoxdale combines moraine and kame with delta.

SOME DESCRIPTIVE DETAILS OF MORAINES AND BORDER DRAINAGE.

A brief description of a few of the better examples of moraines and border drainage will now be given. The morainic deposits associated with the ice-front may be divided into three or possibly into four classes:

1. *Frontal or marginal moraines, resembling those of the Great-Lake lobes in the West.*—These are ridges of bowldery till in which clay is a relatively large constituent. They have usually a swell-and-sag topography, but also more or less knob-and-basin development. In the West this type of moraine is most characteristically developed on a plain country along the straight or gently curving margin of a great lobe. There is but one typical and strongly developed example of this class in Berkshire county. This fragment runs three miles southeast from Pittsfield.

It is about a mile broad, has a beautifully undulating surface, the higher swells reaching an altitude of sixty feet above the surrounding plain. Clay is a large factor in its composition, and it originally carried a great number of bowlders on its surface. It is built out across an open part of the Housatonic valley and was made by an ice-tongue which came from the north out of the Hoosic valley. The fact that this tongue deployed upon an open plain caused it to expand as it advanced, and no doubt gave its moraine the character described rather than that of the next class of deposits, which is much more common in the Berkshires. There are moraines of this type, but not so well formed, west of Hoosick Falls, N. Y., and there is a small fragment of similar character three-fourths of a mile north of Ashley Falls.

2. *Terminal moraines of ice-tongues.*—This class of moraines is the best developed and the most common type in the Berkshires, but it has both advantages and disadvantages as a means of tracing the ice-borders. It is always fragmentary and limited in extent, being confined in its best developments to the terminal parts of sharply pointed tongues in relatively deep and narrow valleys. On the other hand, excepting the first class, it is the most easily and most certainly recognizable form of moraine. These deposits are as a rule much coarser in composition than either of the other three classes. Clay is usually a relatively small constituent, and knob-and-basin topography is the common form of expression. In many respects they resemble kames in the forms they take, and many of them might well be mistaken for such if their composition and the circumstances of their occurrence were left out of account. They nearly always contain a large percentage of gravel, and in this, too, they remotely resemble kames. But as a rule they contain some clay and a very large proportion of the coarser sediments, sometimes being composed mainly of cobbles and bowlders, with only a filling of gravel and sandy clay. Not infrequently small bodies of stratified sand and gravel occur in them. They may be distinguished from kames, however, by the fact that their best development occurs in narrow valleys where there was free drainage from the ice, while typical kames occur where there was more or less local

FIG. 1.—Looking southeast, one mile south of Cummington, Mass. Knolls of terminal moraine in middle ground.

ponding of the water. They are generally much coarser in composition than typical kames, and as a rule their knobs are lower and their basins shallower.

One of the best terminal moraines found is on the east side of the Farmington river, one mile north of Riverton, Conn. Besides the usual topography and coarse composition of terminal deposits, this one is thickly covered with huge blocks. Another, nearly as fine, was made at the next halt and is partly deposited on a low rock terrace below Hanging mountain, two miles south of New Boston, Mass.

Fig. 1 shows a well-developed terminal moraine one mile south of Cummington,

Mass. Its topography is shown in the middle ground and is very characteristic, the wave-like knolls ranging from ten to fifteen feet in height, with sags and occasional shallow basins between. A broken esker leads to this moraine from the direction of Cummington. The deposit is about a mile wide from north to south. On its outer southward slope there are a few knolls of coarser composition and a small gravel train heads at the moraine. This moraine appears to have blocked the original valley of Westfield river, which formerly went directly south from Cummington, but now goes around to the east through a narrower valley past Swift River.

Fig. 2 is two miles north of Stamford, Vt., and shows a remarkably fine specimen of the deposits of an ice-tongue. The rounded knolls to the right and left below the higher hills are mainly morainic, and are twenty to thirty-five feet or more

FIG. 2.—Looking north, two miles north of Stamford, Vt. Morainic knolls on right and left; end of esker between house and barn.

FIG. 3.— Looking north, two miles south of North Adams, Mass.

in height. The knoll seen between the house and barn is the outer end of an esker and is composed of fine stratified sand. This ice-tongue came from the north and ended in a lake in water probably fifty to one hundred feet deep. The deposits of this moraine are strongly developed for nearly two miles farther north.

Fig. 3 is south of North Adams. The stony knolls in the immediate foreground are part of a fringe of morainic knolls deposited on the outer edge of the great terrace along the base of Hoosac mountain. These knolls partake somewhat of the character of kames in their composition, but are nevertheless ice-border

deposits. The body of the great terrace upon which this moraine rests is composed of limestone.

3. *Lateral moraines of ice-tongues.*—This class is probably much more extensive, measured along the sinuous length of ice-borders, than all the others put together. But, with a few marked exceptions, it is extremely difficult to recognize with certainty. It is also extremely whimsical in its occurrence. In many situations where one would expect to find it there is no sign of it, while in other places it may be splendidly developed where one would not expect it.

The principal difficulty in recognizing this type of moraine with certainty is its lack of distinctive characters. The place and manner of its occurrence and its association with other border features are the principal guides to its recognition. As would be expected, lateral moraines generally occur on hillsides or the sides of valleys, and often where they are steep. In surface expression and in composition they appear to differ in no important respect from the relatively smooth and featureless stony till of the ground moraine. Sometimes low knolls of coarser composition, and frequently small kames with more or less gravel and sand, are associated with their upper edges, but seldom enter into their composition as an important quantity. Sometimes the mass of drift composing them forms a thick bank —ten or twenty feet, or even more—and their recognition is easy. But oftener it is thin, and their recognition is then difficult or impossible. They are most easily recognized when associated with strong border drainage. Where such a moraine is banked up on a valley side and a river of some volume flowed along the side of the tongue, the bed of the stream puts a very sharp upper limit to the heavier belt of drift, which is then readily recognized as a *submarginal* deposit of the ice. Usually, too, the hillside above the river bed is bare or only thinly coated with drift. Occasionally these moraines are distinct where border drainage was absent or too slight for recognition, their upper limit being determined as before by a line dividing a heavy bank of drift below from a thinly coated surface above. Where border drainage was very strong, a ridge of coarse detritus was

sometimes built along the edge of the ice and left there upon its retreat as a distinct narrow ridge forming the outer bank of the river bed. A beautiful example of this kind occurs on the west slope of Dry hill between Hartsville and New Marlboro. There are three of these river beds at this locality, with vertical intervals of fifteen or twenty feet. The lower one is the most

FIG. 4.—Looking southwest across old channel, two miles south of Hartsville, Mass.

strongly developed and has an outer morainic ridge or bank like a parapet or levee running, with occasional breaks, for two miles or more. It runs along the hillside half a mile east of the Konkapot river and about 130 feet above it. Fig. 4 is a view from the hillside looking southwest across this river bed, which is here about 200 feet wide. The meadow and the cornfield are on the floor of the channel, beyond which the stony parapet ridge may be seen rising ten feet or more above the channel floor. This type of lateral moraine, however, is rarely seen, the more common type being the smooth submarginal form.

Fig. 5 shows a well-defined lateral moraine on the southwest flank of East mountain about three miles northeast of Hancock, Mass. The heavy bank of till rises conspicuously to a certain level above which the drift coating over the rock is thin. The fresh gulley recently cut by a rivulet shows the composition of the mass. The end of this tongue was on the right at Brodie pass.

Fig. 6 is in the valley of Deerfield river near the mouth of Dunbar brook about two miles below Monroe Bridge. This is a remarkable locality. The mountain wall on the left rises over 1,000 feet from the river, in one

FIG. 5.—Looking northeast, three miles northeast of Hancock, Mass.

FIG. 6.—Looking south in valley of Deerfield river, two miles south of Monroe Bridge, Mass.

place rising nearly 900 feet in one-sixth of a mile, thus giving a slope of forty-five degrees. Two moraines are seen here in one view. The near foreground in the center is the outer end of an esker which turns to the left and then to the south at sharp angles. This esker seems to come out of the ravine of Dunbar brook, and appears to have belonged to a narrow ice-tongue which emerged from that ravine into the Deerfield valley whence it spread in the shape of an anchor with a short prong up and a longer one down the Deerfield. The hummocky ground under the hill at the right is full of knobs and basins, and is a part of

the terminal deposit of this tongue. On the lower shoulder of the hill at the left and to the right of the tracks of the snow slides there hangs a fragment of gravelly morainic deposit about 300 feet above the river and belonging to this moraine. A little farther down at a lower level there are heavy morainic deposits continuous with it. These and the hanging fragment are better shown in Fig. 7. It may be noticed in Fig. 6 that the forest

FIG. 7.— Detail of hanging fragment of moraine shown in Fig. 6.

extends up the hillside to a certain line near the top, perhaps 200 feet from the summit, and that the snow slides begin at this same line. Above this line the rock is practically bare, but below it there is a coating of till which supports the forest. The upper limit of the snow slides marks the limit of the ice during the halt next preceding the time of the Dunbar ice-tongue, and the till coating where the several slides occur may be regarded as a thin lateral submarginal moraine. The end of the tongue at this halt was near Zoar.

There are many other good examples of lateral moraines,

especially along the west slope of Hoosac mountain and on the hills north of Williamstown. The latter, however, are very much modified by the strong border drainage that was associated with them. On this account they show a much greater proportion of coarse sediment than usual and also a more varied topography.

(4) *Stoss moraines.*—These are moraines that are banked up on the stoss-side of hills or mountains which stood in sharp re-entrant angles of the ice-front. They have the same general character as the lateral moraines described above, and might perhaps be included with them. Like them they are distinctly submarginal and very smooth in expression and seldom well developed. They differ, however, from the lateral moraines somewhat in the manner of their occurrence and in their associations. Only a few good examples were seen, and none of these appeared to have border drainage associated with them nor any deposits of sand or gravel. The best example of this class was found on the north slope of Miles mountain, a mile and a half southwest of Ashley Falls. The north slope of this mountain is covered with a heavy coating of bowldery till up to about 300 feet above the river, but here the till suddenly grows thin.

All through the Berkshires the normal action of the glacier on the steeper stoss-slopes of mountains was to rub them hard and sweep them clean of all loose materials. Following this rule, the steeper stoss-slopes of the mountains are usually bare or only very thinly coated with drift. The drift sheet of the valleys usually rises somewhat upon their lower flanks, but this cannot be counted as a marginal deposit. However, where a high stoss-slope which would normally be swept bare is found to carry a heavy bank of bowldery till up to a certain height, above which the hill is mostly bare, the explanation seems to be that the bank of till was deposited just under the edge of the ice when the ice-front rested there and was depositing, and hence not sweeping heavily up the slope and over the hill. Stoss-slopes are swept bare most effectively when situated under the ice at some distance back from the edge and when the ice mass is moving freely over the tops of the hills. On Day mountain, which rises south of Dalton, there is a similar deposit.

We have seen in Fig. 4 a good illustration of the work of border drainage. The stream which made this channel was larger than most border streams within the Housatonic quadrangle, for it was the outlet of a temporary lake which filled the Monterey valley and drained a considerable area of land and ice lying to the northwest. None other equal to this was found, but there are good records of border drainage along the base of Peru hill east of Hinsdale; three miles directly south of Tolland; south of Mill River and from New Marlboro south and southwest; along the hill east of Sheffield; north of Salisbury and northeast of Hillsdale, N. Y. West of the quadrangle splendid lines of border drainage run southwest from Brainard, from East Chatham, and from near Spencertown.

In the Taconic quadrangle, so far as investigated, border drainage was found particularly strong where the ice-front rested against the Green mountains between Bennington, Vt., and Williamstown, Mass. It is strong also between North Adams and Cheshire along the flank of Hoosac mountain.

But some of the finest examples of border drainage are those associated with the later outlets of Lake Hoosic. As soon as the retreating ice-front withdrew from the north end of the Rensselaer Grit plateau, Lake Hoosic found lower levels of discharge in that vicinity. At four or five successive halts the outlet river found a new and lower course to the southwest along the front of the ice, and in each position it made a well-defined channel, and built a sandy delta each time where it struck the level of the Hudson estuary.

INTERPOLATION BETWEEN MORAINE FRAGMENTS.

The study of the ice-border in certain localities, where either border drainage or the lateral as well as the terminal moraines were traceable, has furnished the basis of a rule for interpolating re entrant angles around hills and mountains from one terminal deposit to another. One of the best examples showing this relation may be seen in the Housatonic valley south of Pittsfield. The apex of this tongue rested at Lenoxdale, and at this place there is a very conspicuous terminal deposit. A small

amount of bowldery till rises upon the flank of the hill along the east side, but the deposit is mainly a combination of kame and delta. The Housatonic river has found a way around the west side of the deposit. At the north end is a very tumultuous pebbly kame deposit, with pronounced knob-and-basin structure, while to the south the undulations fade away upon a level gravelly surface which terminates in an abrupt bluff at something more than a mile. The bluff has been made more steep by recent erosion. Toward the south the terrace is composed of stratified fine sand, except about fifteen feet at the top, which is coarse gravel. Two or three kames rise as sharp cones forty feet above the delta. One is shaped like a mesa, but narrows into a short but well-developed esker at the north. This tongue projected into Lake Housatonic, and it was in the water of this glacial lake that the delta and kames were made.

The Housatonic valley in this part is bounded on the east by the plateau front and on the west by Lenox mountain. Five miles north of Lenoxdale the plateau front turns to the east and Lenox mountain comes to an abrupt end. The ice-tongue evidently projected between these stolid sentinels. On the east side there appear to be no prominent features marking the ice-border. But on the west side the edge of the ice along the side of the tongue is prettily marked by a small lake and by the channel of its outlet, and in one place by morainic sediments. Two miles and a half north of Lenox and west of the main road there is a slight ridging up of the till into the form of a moraine. To the west this originally extended across the expanded portion of a ravine, coming out of Lenox mountain at the southwest. When the ice stood here it held a small lake in the ravine, and there are some small kames made by a stream which entered this lake from the ice. Eastward and southward, passing three-fourths of a mile east of Lenox, is a small but well defined old river bed which holds its course along the eastward slope nearly down to Laurel lake. Just east of Lenox it branches and takes a lower route a quarter to half a mile farther east and runs about parallel to the same destination. The two branches of the channel represent two positions of the ice-front during this halt.

The Yokun river drains the ravine, and the little lake may be known as Yokun glacial lake. It is near 1,350 feet above sea-level, while the top of the terrace at Lenoxdale is close to 1,020 feet. The base of the terrace is about 960 feet, and this is taken as the basis of measurement. The distance is about four miles from the central part of the terrace to the nearest part of the Yokun glacial lake. Hence the rate of slope along the side of this ice-tongue was nearly 100 feet per mile.

Several other tongues within the area studied afforded similar evidence, but generally the rate of slope indicated was slightly greater, between 100 and 110 feet in a mile. This rate was used as the basis for interpolating from the ends of tongues up to the re-entrant angles at their sides, and has seemed to give satisfactory results. The rate of slope is a little greater where tongues are very narrow, and a little less where they are broad. The average slope along the side of the Hudson lobe, regardless of the tongues and re-entrants, is something between twenty-five and thirty feet per mile.

In the Olean[1] and Salamanca quadrangles Leverett found the side slopes of tongues which reach down the ravines to the Allegheny river to vary between 100 and 130 feet per mile, or slightly steeper than those here reported for the Berkshire region.

Salisbury found the slope at the ice-front at Baraboo, Wis., to be 320 feet per mile. Other estimates of slope quoted by him are for the surface of the ice at points some distance back from its edge, where the slope is always less than at the front.[2]

THE CONTINUOUS AND SEPARATE INDIVIDUALITY OF THE RECESSIONAL ICE BORDERS.

The remains of the ice-borders in the Berkshires are mostly so faint and so fragmentary, and the fragments are so scattered about in the valleys and on the hillsides, with so little appearance of order or arrangement, that a map showing these features alone is unintelligible; it appears for the most part like a mere

[1] Pocket map in Monograph XLI, *U. S. Geol. Surv.*

[2] "Glacial Geology," *Geol. Surv., New Jersey*, Vol. V, pp. 41–3.

aggregation of spots, without any scheme of orderly arrangement, as shown in Fig. 8. This appearance arises not only from the fragmentary character of the evidences, but is greatly increased by two other causes—by the shortness of the average interval between the successive halting places, and by the extreme sinuosity of the ice-front at every halt. If the successive halting places had been farther apart, say fifteen or twenty miles on the average, instead of three and one-half, the continuity of the successive ice-borders would have been more apparent; for each one would have stood out as a recognizable continuous individual, inspite of the fact that it was represented only by a sinuous line of fragments.

In order to see the true relations in the Berkshires it is necessary to revert briefly to some of the larger elements of the situation. The Hudson valley was occupied by a great glacier lobe, low and sharply pointed at the south, but rising to higher and higher levels to the northeast along its eastern border until it overtopped the highest summits of the Berkshires. It was the ice of this lobe that overspread Berkshire county, and it was its retreating eastern limb or margin which made the recessional moraines. Each time the ice-front halted it fitted itself to the rugged topography with which it happened to be in contact at that time, projecting a series of tongues in the valleys and forming high re-entrant angles on the intervening hills. Thus the border of the Hudson valley lobe was made intensely serrate by the ruggedness of the local topography, and it was this that gave the course of the ice-border so many sinuosities and determined the peculiar distribution of its associated deposits. When the Hudson lobe began a movement of retreat, its border drew back all along the line until it reached the place of the next halt; then it halted all along the line, and whenever it advanced it proceeded in the same manner. There is no reason to believe that different parts of the margin of the lobe had dissynchronous movements, such as would be the case if one part retreated while another remained stationary or while still another advanced. Everything we know tends to the conclusion that the movement at all points was synchronous or in unison along the entire side of the lobe.

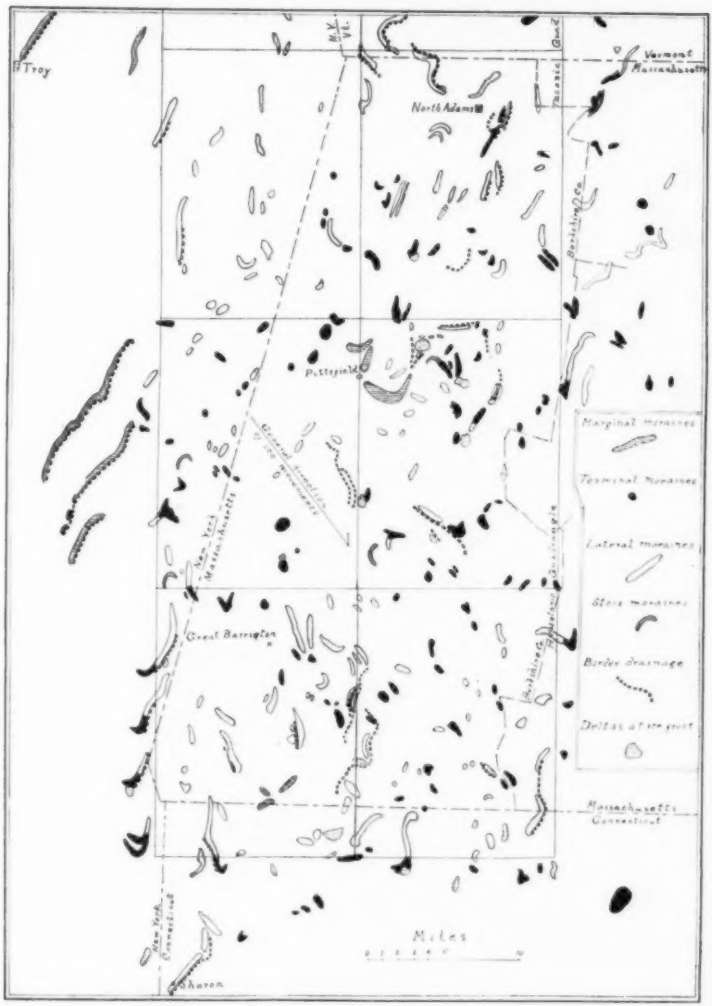

FIG. 8.—This map shows the distribution of morainic and border drainage features without any interpolation. When drawn upon the topographic contour maps, their relations to topography are brought out, and their distribution and arrangement are more intelligible. All moraine fragments which seemed uncertain in their relations to the ice-front are represented on the map as lateral.

These considerations disclose the true relation of the Berkshire ice-tongues to the Hudson lobe. They were absolutely dependent upon that lobe for all their movements, and they reflected its conditions in the most intimate way. They were all parts of the lobe itself and constituted a mere fringe along its border. If Berkshire county had been an even plain, either flat or gently inclined, the border of the lobe would have crossed it in straight lines, and the recessional moraines would have been straight and parallel. There would be no reason, then, to suppose dissynchronous movements at different points on the line. The rugged topography has not altered this relation. It produced a fringe of ice-tongues, but those tongues had no dissynchronous movements among themselves. They all advanced at one time, they all retreated at one time, and they all halted at one time.

The conclusion to be drawn from these considerations is that the ice-border at each halt rested on a line which was distinct and separate from the line of the halt that preceded it; so that if perfectly continuous moraines had been made along the entire margin at each halt, these moraines would now be separate and distinct individuals, extremely sinuous, but still roughly parallel and *without any overlappings*. Local differences of climate may have produced some slight dissynchronism of movements, and glacial erosion may have added a little to the same result, but the effects attributable to these causes appear to be so small as to be well within the ordinary width of the moraines. Sometimes moraines are a mile and one-half to two miles wide, and they are then generally composed of three or four secondary ridges more or less distinct, suggesting waverings or changes in the position of the ice-front during the halt. Border drainage channels often show the same waverings. But whether these very slight waverings were due to general or local causes is not yet clear.

Alpine glaciers, on the other hand, show widely dissynchronous movements.[1] While one advances, another retreats, and

[1] H. A. REID, "Variations of Glaciers," reports in several recent volumes of the JOURNAL OF GEOLOGY.

still others may be at a standstill. The cause of this lack of unison in movements is found in the fact that Alpine glaciers are fed from separate snow-fields. Their gathering grounds are on the high flanks of mountain peaks or ranges, and each glacier has its own basin, or cirque, in which its snow accumulates. The varying conditions of snowfall in individual storms, and in different months and years and periods of years, furnish abundant reason for their individual peculiarities and dissynchronous movements.

But although their forms often bore some resemblance to Alpine glaciers, the ice-tongues of the Berkshires were not of the Alpine type. They were not fed by independent snow-fields, but were all simple offshoots from one ice-mass — the Hudson valley lobe. They were all fed from one source, and whatever affected that source affected them all alike. There appears to be ample reason, therefore, for believing that the recessional halts in the Berkshires were separate individuals without overlappings.

But while these conclusions may be safely applied to the Berkshires, and would probably be applicable in other regions where the relations were equally simple, it is not intended to imply that they would be a safe guide everywhere. There is much reason to believe that the great lobes, like the Hudson valley and Lake Ontario lobes, had movements somewhat dissynchronous, so that as between two such lobes the principle of correlation here suggested might not apply.

In the Berkshires, however, this seems to be the one thing needed. It seems to furnish the only possible basis of correlation by which the fragments of the recessional moraines can be connected together and the ice-borders reconstructed as they actually existed. With one or two ice-borders clearly made out in continuous form for a sufficient distance to show their general trend, with branching and interlacing series of terminal deposits made by ice-tongues at consecutive halts in the main valleys, and with a moderate amount of interpolation between adjacent fragments applied according to rule as given above, it becomes possible to reconstruct in continuous form all of the recessional ice-borders

of Berkshire county. Of course, the certainty of correlation and reconstruction varies in different localities according as it is necessary to use more or less interpolation. For example, across Mount Washington the course of the ice-borders is almost wholly interpolated. The few fragments of moraine found on the mountain are so far from those in the surrounding valleys that their connections must remain uncertain. These lines, however, are not drawn by mere guess, but as closely by rule as possible, and are projected from points of observation in the valleys near by. The terminal deposits in the valleys on both sides of the mountain are mostly well developed and form an excellent basis for correlation. About the same amount of interpolation was used on Greylock mountain. The lines across Hoosac mountain are somewhat less certain, but they are based on excellent data in the valleys on both sides. The Green mountains, the northern part of the Taconic range, and the Rensselaer Grit plateau have not yet been sufficiently studied for mapping. In the rest of the area interpolation is used in less degree and is generally simple, and reconstruction of the ice-fronts is correspondingly easier.

THE BECKET AND LENOXDALE MORAINES.

Where ice-borders are represented by moraine fragments scattered in such disorderly fashion, it is fortunate to find two or three sections of some length in which the evidence for continuity is complete. Such sections establish the general trend of the ice-border and form excellent bases for the correlation of other less clearly connected fragments of near-by earlier and later borders. The second moraine, as shown on Figs. 9 and 10, is substantially continuous from Tolland to Colebrook, only a very little interpolation being required to complete the line between these places. There are a number of other sections of similar length, the continuity of which is quite clear. But besides these there are two longer sections, which in their combined length reach entirely across the Housatonic quadrangle from southwest to northeast. These are the Becket and Lenoxdale moraines, parts of the sixth and eighth, as shown in Figs. 9 and 10.

Beginning at a point about three miles northeast of Tyringham, the Becket moraine is readily recognizable as a continuous line for a distance of twenty-five miles, or to a point two or three miles northeast of Plainfield. The continuity of this line is evident simply from the closeness of the moraine fragments of which it is made up, and from its distinct separateness and lack of confusion with the fragments of other earlier and later moraines. The line of fragments stands out quite clearly as a unit in Fig. 8, where no interpolation is employed.

The other section is part of the Lenoxdale moraine. This one has much larger tongues and re-entrants, and might at first seem an unlikely case for clearly established continuity. But its relation to Lake Housatonic fixes the contemporaneity of two of its most widely separated tongues. As we have seen above, the great kame-and-delta terrace at Lenoxdale was built in a lake. If there had been no obstruction in the narrow valley of the Housatonic river below Glendale, the water would have passed out by that course as it does now, and there would have been no lake. There is another great kame-moraine deposit, with some delta gravel, at Glendale, showing conclusively that the ice-border stood there also in a lake. More than this, at the Konkapot col, three miles east of Great Barrington, there is the head of a well-marked eroded river bed which was the outlet of the lake in question, and this outlet is at an altitude of about 1,000 feet above the sea level—about the same as the top of the fine sand in the Lenoxdale delta. There is also a beautifully cuspate lake delta at East Lee at the same level, and the highest part of the Glendale deposit stands at about the same. It seems plain, therefore, that the ice-tongues at Lenoxdale and Glendale stood in their places at the same time, and that there was between these tongues a deep, wide re-entrant around Lenox mountain. From Glendale to Hillsdale, N. Y., the closeness of the moraine fragments and their distinct separateness from the fragments of earlier and later lines leave no doubt of the continuity of the Lenoxdale ice-front. This section also is about twenty-five miles long.

The Becket and Lenoxdale moraines are roughly parallel,

and between their ends, which lap past each other, there are fragments of another moraine at East Lee and Washington. Supposing the successive moraines to be distinct individuals, as stated above, the correlation of fragments of other moraines with either of these continuous sections has the same significance as though they were correlated with the same point in a single series. These relations furnish the basis for reconstructing the several recessional ice-borders.

BRANCHING AND INTERLACING SERIES OF TERMINAL MORAINES.

With the aid of two or three ice-borders made out clearly as continuous units for distances of twenty or twenty-five miles, like those just mentioned above, it becomes possible to reconstruct other near-by ice-borders whose continuity is not so clear when taken by themselves. This can be accomplished by the correlation of branching and interlacing series of terminal moraines in their relation to the identified continuous lines.

The most favorable condition for the formation of a complete series of moraines that shall make a perfect record of the successive recessional halts occurs where a deep, narrow valley drains directly away from the receding ice-front and keeps this relation during many successive halts. This is the relation of the Farmington valley. From its head near East Lee it cuts through the plateau a few miles to the east, then turns to the south, and passes out of the county and out of the Housatonic quadrangle near the southeast corner. The earliest ice-border which rested within the area of the Housatonic quadrangle crossed the extreme southeast corner a mile west of West Hartland. It was a re-entrant angle of the ice-front and is a faintly developed feature, but it is here designated as No. 1 of the series. Counting up the moraines in the Farmington valley, beginning with the one north of Riverton as No. 2, we find that the deposit at West Becket on the line of the Becket moraine is the sixth, the one east of East Lee the seventh, the one at Lenoxdale the eighth, and the one at Pittsfield the ninth. The moraines of this series are distinct, well-formed individuals, and would be readily recognized by any experienced observer. A careful

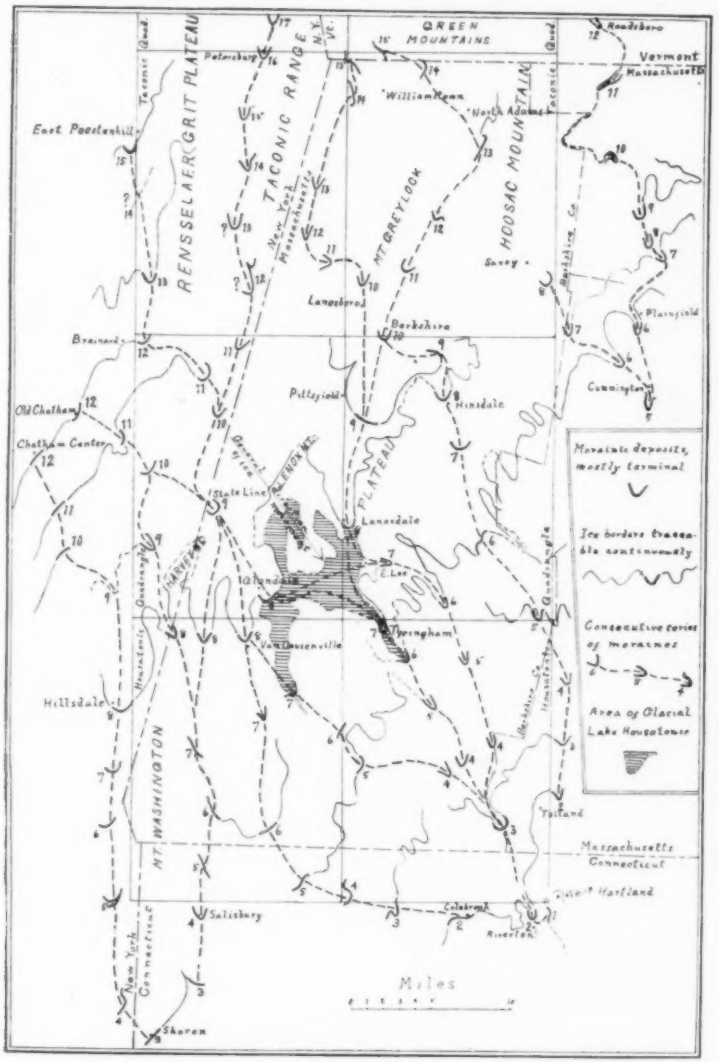

FIG. 9.—This map shows the scheme by which the moraine series in one valley is correlated with that in another parallel or branching valley. This scheme, supplemented by the rule of interpolation between adjacent ice-tongues of the same halt, forms the theoretical basis for the reconstruction of the several recessional ice-fronts, as shown in the next map. Some of the best lines, which are traceable with substantial continuity, are shown upon this map. Nos. 2, 6, 8, and 12 form the principal foundation for the application of the scheme. The area of Lake Housatonic is represented in order to show the contemporaneity of the Lenoxdale and Glendale ice-tongues.

study of the valleys in which these tongues lie shows further that there are no other recognizable terminal deposits in them. The deposits at Cold Spring and at North Otis show some complexity, because they are spread up and down the valley a little more than usual, in each case showing earlier and later phases of deposition which are one to two miles apart. But a little experience enables one to recognize the fact that deposits like these are due to the waverings of one halt.

South of East Lee the deep Tyringham valley comes in from the southeast. Over the col at its head it is continuous with the valley of Clam river, which joins the Farmington at New Boston. Counting the moraines up the valley again from Riverton by way of Clam river, we find the deposit at Tyringham to be the seventh or the same as that at East Lee, with the eighth at Lenoxdale as before. Here we have a branching series in which the first two are common, but north of the second one two parallel branches run up to the seventh. The branches diverge so little that they are not over four miles apart at any point. In a simple branching series like this it can hardly be doubted that the two deposits which stand as No. 4 in each series belong together as parts of one halt line, and the two deposits marked No. 5 as parts of a different later line, No. 6 as parts of still another line, and No. 7 as parts of still another. At Lenoxdale the two branches reunite as one.

From New Boston another series may be followed more to the west past Montville, New Marlboro, Hartsville, and the Konkapot col to Van Deusenville, where again is found the Lenoxdale moraine, which is the eighth of the series. This series, however, is not quite so good as either of the others, for it does not lie in a single trough or in a pair of head-joined valleys, like the other two, but crosses the hills from the Farmington valley to the Housatonic.

The moraine north of Riverton is easily recognized as part of a line which runs westward to Colebrook. Beginning at this place as No. 2, another series may be followed northwest to Van Deusenville as before, but by a different route through Norfolk, West Norfolk, East Canaan, Ashley Falls, and the hillside south-

east of Great Barrington. Part of this series is somewhat less distinct than the preceding, but still is clear enough, and here we have four branching series of six terminating in No. 8, which is well determined as a continuous line.

In order to get the best possible basis for carrying the ice-borders by interpolation across Mount Washington, it was necessary to extend investigations some distance to the south beyond the limits of the quadrangle. The Housatonic valley passes close along the base of the mountain on the east, and the Copake valley along its west side in New York. In the latter valley there is a fine series of terminal deposits, which may be counted from the north, beginning with the Lenoxdale moraine at Hillsdale as No. 8. The seventh, then, is at Copake Furnace, the sixth at Boston Corners, the fifth about two miles north of Millerton, the fourth at Indian Lake, and the third at Sharon, Conn. This is as far as this series has been made out, but it is as strong and distinct as the series in the Farmington valley. At Sharon, and for three miles northeast, there is a well-defined moraine running along the edge of a bench near the northwest base of a mountain ridge extending in the same direction. The ridge is east of the moraine, and between the two there is a well-defined abandoned river bed averaging about an eighth of a mile wide. Beardsley pond lies in the course of this channel. The east side of the moraine facing the river bed is gravelly and sandy most of the way. At a point about three miles northeast of Sharon the river bed seems to have an abrupt beginning on the brow of a low ridge, overlooking Beaslick pond to the north 100 feet lower. There is no sign of such a river bed in that direction. The moraine turns to the north a mile south of the pond and changes its character, becoming a heavy till ridge of smooth form with very little sand or gravel. East of this ridge, and separated from it by the sharp depression in which Beaslick brook flows, is another heavy, smooth till ridge of precisely similar character. These ridges are about eighty feet above the adjacent low ground, but may not be wholly composed of drift. North of the pond these ridges are nearly parallel, but at the pond they diverge and turn away in opposite directions. The

eastern one turns off to the east and is soon lost on the hill above Salmon creek, while the western one follows the bench to Sharon as described.

The relations here are highly significant and afford a strong basis of correlation around the two sides of Mount Washington; for evidently the large river, which seems to start so abruptly where the two moraines diverge, came from the northwest along a crease or depression in the ice. The ice-sheet advancing down the Copake valley on the west side of Mount Washington pressed eastward over the relatively low ground north of Sharon and west of Lakeville, and met the ice coming down the Housatonic valley on the east side of the mountain. A moraine along the southeast flank of Mount Washington north of Lakeville appears to belong to this same halt and indicates that a large portion, probably nearly one-half of the mountain, remained at that time uncovered as a nunatak. All of the drainage of the nunatak and of as much of the adjacent ice-field as sloped toward it found its way of escape along the crease between the two lobes and thence down the old river bed past Sharon. Since the ice has disappeared, the bed of the river in the ice-crease has gone, and no trace of it remains. This is why we find the river bed appearing suddenly where it emerged from the crease.

The significant fact which this relation establishes is this, viz., that the two moraines which diverge from the crease belong to the ice-border of one and the same halt. This enables us to say that if the Sharon moraine is No. 3, in a series numbered down from Hillsdale, then the east moraine at the crease is the same number counting down the Housatonic from Van Deusenville. Part of the latter series is not so strong as that between Sharon and Hillsdale, for the moraines in the Housatonic valley are mostly faint and weak. Still, well-developed small fragments may be seen at Salisbury for No. 4, west of Chapinville for No. 5, near Ashley Falls for No. 6, and on the mountain flank southeast of Great Barrington for No. 7. It would be hard to think of a more beautiful correlation between two series than that which is furnished by the peculiar relations of the Sharon glacial river.

There is another series of terminal deposits east of the Farmington valley almost as fine as those of the Farmington and Copake valleys. From the moraine north of Riverton the lateral moraine and border drainage is quite clear most of the way along the valley side north to Tolland, where the ice-border turned to the east. Starting with the deposits near Tolland as No. 2, there is a well-defined series running to the north past North Blandford, Becket, Washington, and Hinsdale to the moraine north of Dalton, which is the ninth in the series and the same as the Pittsfield moraine. The deposits at Tolland are rather faint, but all the other members of this series are well developed.

Passing out of Berkshire county into New York we may extend the series from the Lenoxdale moraine to the northwest corner of the Housatonic quadrangle. This may be done by following the series of terminal deposits from Van Deusenville as No. 8 past State Line, and thence north and west past Lebanon Center to moraine No. 12 east of Brainard. From here the series may be extended north to No. 15 at East Poestenkill. Outside of the quadrangle a series may be followed from No. 8 at Hillsdale to No. 12 at Chatham Center. Or, another good line runs from No. 8 south of Green River past Austerlitz to No. 12 at Old Chatham.

From the Pittsfield-Dalton moraine (No. 9) the series may be extended northward by two routes so as to surround Mount Greylock. One line runs through Berkshire, Cheshire, Adams, and North Adams to two lateral moraines northeast and north of Williamstown, the last one being No. 15 in the series. The first four are terminal deposits. Berkshire village is just north of the col between the Housatonic and Hoosic valleys, and the terminal deposits there and all those along the Hoosic river north of there, were laid down in the water of Lake Hoosic. From North Adams down, the lake was so deep that the terminal deposits are unrecognizable, and the positions of the tongues have been determined mainly by lateral deposits and border drainage features on the flank of the Green mountain range at and above the level of the lake. At Williamstown the lake was 500 feet deep. The conditions along the flank of the Green

mountains favored the making of a strong record of glacial border deposits at every halt. The drainage features especially are very pronounced, and their value for determining the recessional series is almost equal to the terminal deposits of deep valleys with free drainage.

The other series running north from Pittsfield passes by way of Lanesboro and the Hancock valley to two lateral moraines on the flank of the Taconic range west and northwest of Williamstown, the last one being No. 15 as in the other series. Some of the individual deposits of this series are not so strong as those of the series through North Adams.

One of the best series found is that which extends northward in the Lebanon and Berlin valleys along the west side of the Taconic range, but the study of these valleys is not yet completed. Beginning with the tongue at State Line as No. 9, the series runs directly north past Lebanon Springs, Stephentown, and Berlin to No. 17 near North Petersburg, the last four being formed in a deep lake. Four more well-developed moraines lie west of Hoosick Falls. No. 20 passes Johnsonville and enters the city of Troy from the northeast, and No. 21 crosses the Hoosic river three or four miles below Johnsonville, but it is not known whether or not this last one touches the area of the Taconic quadrangle.

Going back now to the country bordering the east side of Berkshire county, we find the Becket moraine (No. 6) extending northeast to Plainfield. The splendid terminal moraine a few miles to the south, near Cummington, seems to belong to No. 5. From this point two series may be traced—one to the northwest up the Westfield river to Savoy, and the other directly north past Plainfield and down the east branch of the Chickley river to the Deerfield at Zoar (No. 10). On account of its depth and narrowness, the deposits in the Deerfield valley are unusually strong and clear, and the series quite easily made out. From Zoar the series may be followed past Monroe Bridge and Readsboro, whence one branch goes northwest past Hartwellville to Woodford on the top of the Green mountain range, while another longer series follows up the Deerfield past Davis Bridge, Sears-

burg, and Somerset to a point about three miles northeast of the northeast corner of the Taconic quadrangle, where No. 16 is found, about four miles south of Grout's mill.

Among these branching and interlacing series of terminal deposits there are several courses by which a complete series may be followed continuously across the county and across the two quadrangles from southeast to northwest. The Farmington-Housatonic-Hoosic series covers the whole interval, and shows that between the southeast and northwest corners of the county the ice-front halted fourteen times, while in crossing the two quadrangles it halted twenty or twenty-one times, the uncertainty depending on the unfinished work at the northwest corner of the Taconic quadrangle.

Along the west side of the two quadrangles on the less rugged slope to the Hudson the recessional moraines can readily be traced as continuous individuals. They run here in lines more nearly straight, the border drainage was strong, and the series as a whole can be made out with a completeness not possible within the limits of Berkshire county. However, so far as the several interlacing series of fragments in the mountain valleys are complete, they may be regarded as safe counters for the enumeration of the recessional series, and if, as assumed above, the several ice-borders of the recession are separate and distinct individuals without overlappings, then the series may be regarded as complete, provided there have been no errors or omissions in observation. In order that there might be the least possible chance of such errors or omissions, the counts have been confined as far as possible to the valley deposits; for in Berkshire county the morainic deposits are concentrated in the valleys and are nearly always more strongly developed there than elsewhere. A series of terminal deposits like any of the stronger ones mentioned above is in fact a series of accentuated points in the recessional moraines. When series do not follow valleys, but cross hills and mountain ridges, they are not by themselves so reliable. Such in part are the two lines from Colebrook and New Boston to Van Deusenville. But where they occur as supplementary lines between clearly defined valley series they may have considerable corroberative value.

In the interlacing series shown in Fig. 9 a considerable number of the morainic deposits and other ice-border features have not been used, as may be seen by comparison with Fig. 8. When these are all studied in their relation to the several members of the interlacing series, it is found that, with two or three unimportant exceptions, they all fall into line in one or another of the several halting places of the ice-front. Beginning at the southwest with any particular member of the Copake valley series, as for instance No. 6, and going northeast across the interlacing series and noting each deposit numbered 6, the course thus marked out will represent roughly one halt of the ice-front. Then by carefully studying the topography between tongue deposits in adjacent valley series, and allowing for its influence upon the motion of the ice, and making use of all intervening ice-border phenomena as shown in Fig. 8, a fairly accurate restoration of the ice-front at that halt can be made. In doing this the rule outlined above for interpolating around re-entrant angles on mountains or other features with high relief should be followed faithfully. That is to say, in order to restore the ice-front across a mountain ridge between the terminal deposits of two ice-tongues, the tongues having average dimensions for the Berkshire region, allowance should be made for a slope of 100 to 110 feet per mile along the side of the tongue from its point up to the re-entrant angles on its sides.

These are the methods by which the remarkably sinuous ice-borders of Berkshire county have been restored, as shown in Fig. 10. The mean course of any one of them represents the general course of the border of the Hudson valley lobe at that halt. These mean lines are bent from a direct course only by the larger features of topography, such as Mount Washington and the higher ranges to the north. In each one of the sinuous lines represented every point projecting away from the ice-field (generally toward the southeast) is an ice-tongue of more or less pronounced development, and every point projecting back toward the ice-field is a re-entrant angle.

In constructing these lines I have made them continuous where they represent ice-border features actually observed, and

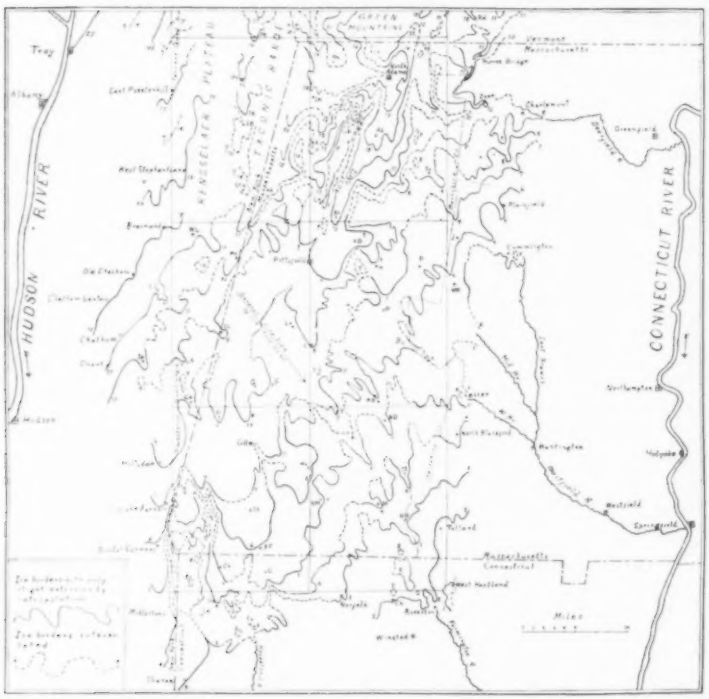

FIG. 10.—This map shows the final results of a reconstruction of the recessional ice-borders by the method set forth in this paper. Parts of the Hudson and Connecticut rivers are included in order to show the general relations of the ice-borders to these two great valleys.

In Connecticut, C = Canaan, Ck = Colebrook, Cn = Chapinville, Fv = Falls Village, Lk = Lakeville, and Sb = Salisbury.

In New York, A = Austerlitz, Bn = Berlin, EC = East Chatham, GR = Green River, Mt = Mt. Lebanon, Pt = Petersburg, SB = South Berlin, Sp = Spencertown, Stn = Stephentown, and WL = West Lebanon.

In Vermont, Rd = Readsboro and St = Stamford.

In Massachusetts, Ad = Adams, AF = Ashley Falls, Al = Alford, B = Becket, Bk = Berkshire, Cr = Cheshire, CS = Cold Spring, D = Dalton, EL = East Lee, G = Glendale, GB = Great Barrington, H = Hinsdale, Hk = Hancock, Hv = Hartsville, J = Jordansville, L = Lenoxdale, Ln = Lanesboro, Lx = Lenox, M = Montville, NA = New Ashford, NB = New Boston, NM = New Marlboro, NO = North Otis, P = Peru, S = Stockbridge, Sh = Sheffield, SL = State Line, Sv = Savoy, SW = South Williamstown, T = Tyringham, V = Van Deusenville, W = Washington, WB = West Beket, Wn = Williamstown, and WW = West Worthington.

I have extended them beyond these features by interpolation for a short distance, which may be defined as interpolation to the first degree. By this I mean that degree or amount of interpolation which any cautious and experienced observer would make without hesitation. Geologists who study the indurated rocks, especially in a drift-covered region, are continually driven to interpolate between outcrops. Where the distance is not great and the relations appear to be simple, such interpolation is regarded as a matter of no great difficulty, seldom involving serious risk of error, and requiring no very critical weighing of the phenomena for its application. It is like interpolating the course of a brook through a wood lot or a thicket when the places of its entrance and exit are known and the general relations are seen to be simple. Of course, many small errors will inevitably arise from such interpolation, but they seldom affect the larger elements of the problem in hand. The first degree of interpolation goes but a little way beyond what we can actually see. Where the restoration of the ice-borders in Fig. 10 has been accomplished by the use of interpolation which involves more uncertainty than the first degree, as here defined, I have drawn them as broken lines. Of course, the limit of the first degree of interpolation is an arbitrary one, but I have endeavored to keep on the safe side. The higher mountain areas, like Mount Washington, showed very few recognizable ice-border features and the course of the ice-borders across these areas is drawn almost wholly by interpolation. In general, therefore, the margin of error is much larger here than in the lower areas. Nevertheless, an effort was made to minimize such errors by carrying the studies over all the contiguous low ground, even where some of this extended outside of the quadrangles.

CONCLUSION.

If these studies have been guided by right methods and the interpretations made on a foundation of correct principles, we seem justified in concluding that the ice-border which retreated to the northwest across Berkshire county was the eastern edge or limb of the Hudson valley lobe; that the positions occupied

by the ice-border at its successive recessional halts were distinct individuals without overlappings; that by the faintness of the moraines and other border phenomena, the halts may be judged to have been of relatively short duration, although when we consider the number of halts which occurred within the interval of fifty miles it can hardly be said that the retreat of the ice-front was rapid, or that it was a sudden dissolution with great floods, as pictured by Dana[1] and others.

That this ice was Hudson ice and came over the Berkshires from the central axis of the Hudson valley seems to be indicated further by the fact that within the area of the two quadrangles studied no stones or bowlders were found which might be suspected of coming from Canada or from the Adirondacks. It seems that the Adirondack ice never crossed to the east side of the Hudson-Champlain trough, and further that any bowlders which may have started from Canada down the axis of this trough found it impossible to keep the line of that axis far enough to reach the Berkshires. The continual divergence of the ice to one side or the other of the axis appears to have sidetracked all the Canadians before they got so far south. The same fact seems to account in part for the very local derivation of nearly all the drift in the Berkshires. Exceedingly little came from points as far north as Whitehall, N. Y. The great spreading ice-stream which moved down the Champlain-Hudson trough domineered those valleys through every stage of the glacial invasion and was never diverted from its course.

In his recent admirable report on the glacial geology of New Jersey, Salisbury observes that "the edge of the ice might have halted in one place and not at another at the same time. Moraines of recession are therefore sometimes not traceable for long distances."[2]

[1] J. D. DANA, "The Flood of the Connecticut River Valley from the Melting of the Quaternary Glacier," *Am. Jour. Sci.*, III, Vol. XXIII (1882), pp. 87–97, 179–202, 360–73; Vol. XXIV, pp. 98–104. C. H. HITCHCOCK, "The Glacial Floods of the Connecticut River Valley," *A. A. A. S., Proc.*, Vol. XIII (1883). WARREN UPHAM, "A Review of the Quaternary Era, with Special Reference to the Deposits of Flooded Rivers," *Am. Jour. Sci.*, III, Vol. XLI (1891).

[2] "Glacial Geology," *Geology of New Jersey*, Vol. V, p. 89.

The entire glaciated area of New Jersey falls within the domain of the Hudson lobe, and its relation to that lobe is precisely the same as that of Berkshire county, Mass., except that the former lies on the west limb of the lobe and near the extreme limit of glaciation. If the principles used for Berkshire county are valid, they ought to be equally valid for the west slope of the Hudson valley, including northern New Jersey. We have seen above that a discontinuous character in the recessional moraines is not necessarily due to dissynchronous oscillations of the ice-front, and that, at least in the Berkshires, there are ways in which the continuity of the successive ice-fronts can be demonstrated, despite the extremely fragmentary character of the morainic deposits.

FRANK BURSLEY TAYLOR.

FORT WAYNE, IND.,
May 7, 1903.

THE UPPER RED BEDS OF THE BLACK HILLS.

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INTRODUCTION.

DESCRIPTION.

General description of the red beds of the Black hills.
Details of stratigraphy.
Microscopic characters.
Chemical analysis.

DISCUSSION.

Theories for the origin of the color of red beds.
Application of theories to the red beds of the Black hills.

GREEN VARIATIONS.

INTRODUCTION.

THIS paper describes the upper red beds of the Black hills and inquires into the origin of their color.

The red beds of the Black hills are composed of from five to six hundred feet of red sandstones and shales with gypsum in the upper part and a bed of limestone toward the base. This limestone enables a threefold division of the rocks.[1] The Opeche formation at the base of the series consists of a hundred feet of unfossiliferous red shaly sandstones. These lower red beds lie apparently conformably upon vari-colored calcareous sandstones of Carboniferous age, the line of division being an abrupt change in color. Separating the upper and lower red beds, and lying conformably between them, is the Minnekahta limestone, which is purplish-gray in color, about forty feet thick, persistent in its occurrence, and contains Permian fossils. The upper red beds average four hundred feet in thickness, and are composed of unfossiliferous red sandy shales and interbedded gypsum unconformably overlain by more somber-colored rocks of Jurassic age. These upper red beds, named the Spearfish formation, are the subject of this paper.

[1] N. H. DARTON, "Geology and Water Resources of the Southern Black Hills," *Twenty-first Annual Report U. S. Geological Survey*, Part IV (1901), pp. 513–19.

DESCRIPTION.

General description.— The accompanying map shows the Spearfish formation girdling the Black hills in a crude ellipse, one axis of which is about eighty miles and the other forty. The width of outcrop varies considerably, but averages two miles. The greatest areal extent is in the vicinity of Sundance, where the formation is eight miles wide; near Cascade Springs the

Red Butte, northeast of Cambria, Wyoming. Spearfish red beds capped by 30-foot bed of gypsum.

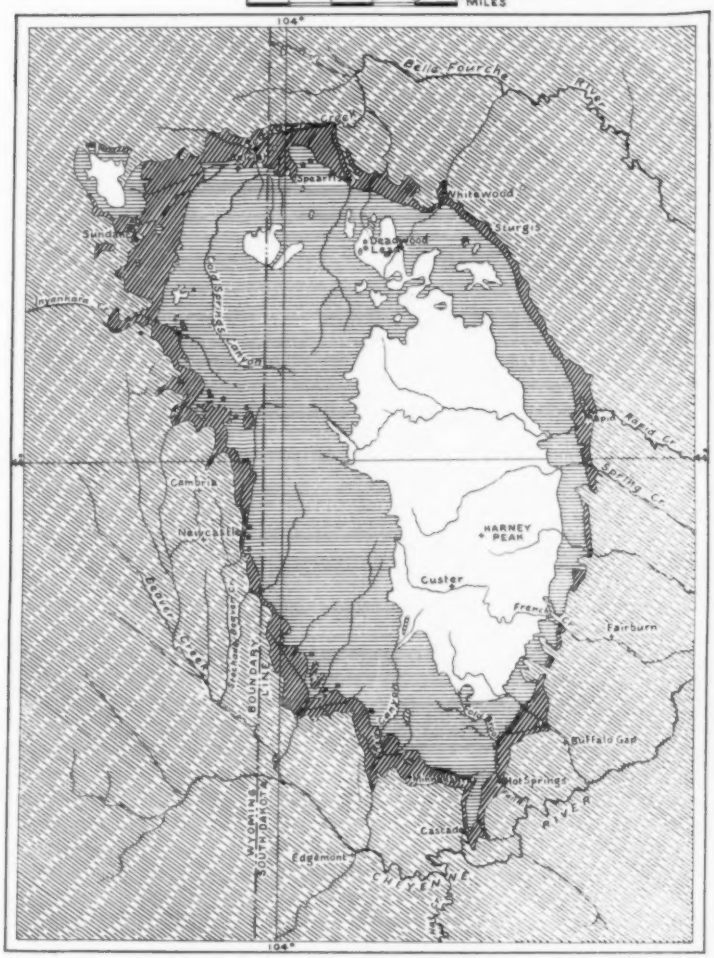
width, because of the steep dip there, diminishes to less than a thousand feet.

Structurally these rocks conform to the contiguous sedimentary formations by dipping on all sides from the central mass of the Black hills. This general dome structure, however, is varied by subsidiary folding. At the inner limit of the upper red beds, toward the center of the hills, the underlying purple limestone slopes upward, and the line of contact, where the softer red

MAP OF THE UPPER RED BEDS OF THE BLACK HILLS

N.H. DARTON AND G.B. RICHARDSON

SCALE 0 5 10 15 20 MILES



SECTION THROUGH HARNEY PEAK

POST SPEARFISH SEDIMENTS. SPEARFISH RED BEDS. PRE-SPEARFISH SEDIMENTS. CRYSTALLINE ROCKS.

rocks have been eroded from the surface of the limestone, is extremely irregular. The outer limit of the formation is emphasized by an escarpment formed by Jurassic and Cretaceous sandstones.

Streams coming from the high central area of the Black hills generally flow directly across the red beds, yet occasional creeks, like Red Water in the vicinity of Beulah, flow for some distance parallel to the strike of the red rocks before leaving them. The divides, however, are low and the general appearance of the Spearfish formation is that of a valley. This red valley is very conspicuous. No timber and very little vegetation are supported by the underlying rocks. Erosion has cut gullies in the shales and has exposed prominent gypsum-capped buttes, while the color contrasts of the rich red rocks and pure white gypsum form striking effects.

Details of stratigraphy.—The stratigraphy of the Spearfish formation is shown in detail by the following:

COLUMNAR SECTIONS.

(The heavy lines mark respectively the upper and lower contacts of the Spearfish red beds.)

1. ONE MILE UP COLD BROOK FROM HOT SPRINGS.

	Feet.	Inches.
Upper contact covered.		
Gypsum	10	
Red sandy shale	3	
Massive white gypsum	3	
Fine red shale	15	
White gypsum	..	9
Red clayey sandstone	8	
White gypsum	..	8
Red clayey sandstone	15	
Massive mottled gypsum (red sandy clay admixture)	35	
Red sandy shale with interlacing veins of gypsum 1 inch to $\frac{1}{16}$ inch thick	3	
Massive white gypsum	3	
Green-drab shale	1	3
Chocolate-brown hackley shale	5	
White gypsum	4	
Hard light-red clayey sandstone	..	8
Green shale	..	¼
Hackly brown sandy shale with a 3-inch streak of green clay	15	

	Feet.	Inches.
Covered to lower contact.		
At contact red, clayey sandstone with minute specks of glistening quartz.		

Purple limestone (Permian).

II. THREE-FOURTHS OF A MILE UP COLD BROOK FROM HOT SPRINGS.

Massive buff sandstone (Jurassic).

Rather coarse dark brick-red sandstone with few streaks of green clay	20+	
Concealed.		
Mottled gypsum (admixture of red clay)	4	
Reddish sands with thin green streaks	..	8
White gypsum	..	2
Rather coherent bright red sandy shale with few small green specks	25+	
Concealed.		
Red sandy clay.		
(Abrupt change.)		
Massive pure white gypsum	18	
Light red clayey sandstone with network of wafer-thin gypsum veins	10	
Massive white gypsum	8	
Red sandy clay	2	
Massive white gypsum	20	
Red sandy clay	40+	
Lower contact covered.		

III. HEAD OF SHEPS CANYON, EAST OF CASCADE SPRINGS.

Massive yellowish sandstone with few small basal pebbles of quartz (Jurassic)	30–40	
Erosional unconformity.		
Massive chocolate-brown, sandy shale	30+	
Dark brown-red clayey sandstone with green clay streaks, not continuous, and thin interlacing gypsum veins	30+	

IV. CANYON NORTHEAST OF CASCADE SPRINGS.

Alternating red sandy shales and gypsum of undetermined thickness.		
Hard red clayey sandstone with green streaks	..	8
Red clayey sandstone with thin partings 2-inch ± of pure white gypsum	10	
Red sandy shale	10±	
Pure white massive gypsum	3	6

	Feet.	Inches.
Purple limestone (Permian)	30+	

V. ONE-HALF MILE SOUTH OF CASCADE SPRINGS.

Covered to upper contact.		
Red shales.		
White gypsum	5	
Red sandy shale	20	
White gypsum	20	
Red sandy shale	15	
White gypsum	5	
Red sandy shale	100	
Covered.		
Light red sandy clay.		
White gypsum	20	
Red sandy shale	40	
Mottled gypsum (white gypsum with red clay admixtures)	20	
Red sandy shale.		
Gypsum	3	
Red sandy shale.		
Concealed	100±	
Gypsum.		

Purple limestone (Permian).

VI. AT CASCADE SPRINGS.

Upper contact covered.		
Red sandy shale	15+	
Mottled gypsum (red clay admixture)	10	
Bright red sandy shale	5	
Gypsum	2	
Red sandy shale	3	
Gypsum	10	
Red sandy shale	10	
Gypsum	20	
Red sandy shale	10	
White gypsum with few thin partings of red sandy shale	40	
Red clayey sandstone	20	
Gypsum	20	
Hackly red clayey sandstone	10	
Massive white gypsum	8	
Hard red clayey sandstone	..	6
Red sandy shale	20	
Lower contact covered.		

		Feet.	Inches.
	VII. ONE MILE NORTHWEST OF MINNEKAHTA.		
Jurassic	Fissile green-drab shale	50±	
	Friable white sandstone	25	
Contact covered.			
Chocolate-brown clayey sandstone with patches of green clay		10+	
Concealed.			
Light red sandy shale with some small green specks and streaks		10+	
Chocolate-brown mudstone		4	
Brown-red clayey sandstone with 5′ bed of gypsum and some green streaks		20	
Red sandy shales with some green streaks		30	
Light brick-red clayey sandstone with network of thin gypsum veins		60	
Impure red-stained gypsum		12	
Red sandy shale		..	6
Pure white gypsum		..	2
Red sandy shale		..	1
Green shale		..	½
Red sandy shale with network of gypsum veins		50	
Massive white gypsum		5	
Red sandy shale with network of gypsum veins		15	
Massive white gypsum		20	
Red sandy shale with gypsum veins		5	
Massive white gypsum		3	
Red sandy shale		6	
Massive white gypsum		1	
Red sandy shale with gypsum veins		10	
Mottled gypsum (admixture of red clay)		20	
Brick-red sandy shale		110	
Purple limestone (Permian)		50	
	VIII. FOUR MILES WEST OF MINNEKAHTA.		
Massive, friable sandstone, red superficially; white within. (Jurassic).			
Undulating contact — sharp change.			
Hard chocolate-brown sandy clay.			
	IX. ONE-HALF MILE NORTHEAST OF X.		
Jurassic	Massive fine-grained sandstone; superficially stained red — paler to white within	30–40	
	Shale and thin-bedded drab-green sandstone	15–20	
	Buff sandstone.		
	Massive white sandstone superficially red.		

		Feet.	Inches.
Hard chocolate-colored shale with streaks of green.			

X. ONE-HALF MILE EAST OF XI.

Jurassic	Drab shale	50	
	Buff sandstone	5	
	Drab shale		6
	Yellowish sandstone	15	
	Light red sandstone.		
Dark red shale		40	
Red clayey sandstone with thin beds of gypsum		25	

XI. ONE-HALF MILE FARTHER UP RED CANYON FROM XII.

Jurassic	Fine white sandstone	15+	
	Drab-green fissile shale	50	
	Friable buff sandstone	5	
Brick-red sandstone		15	
Chocolate-brown shaly sandstone		3	
Green sandy shale			3
Fissile chocolate-brown shale		15+	

XII. WHERE RED CANYON LEAVES THE RED BEDS.

Jurassic	Drab sandstone	10	
	Green shale	8	
	Drab sandstone	1	
	Dark-green shale and thin drab sandstone	20	
Chocolate-brown shale with fine specks of glistening quartz		10+	

XIII. WEST OF FANNY PEAK.

Red shale	100	
Gypsum	15	
Red clayey sandstone	100	
Gypsum mottled with streaks and spots of red and purple clay	30	
Red shale	100	
Gypsum	5	
Red shale with network of gypsum veins; thin-bedded at base with no gypsum and thin streaks of green clay	80	
Purple limestone (Permian)	10+	

XIV. RECORD OF WELL AT CAMBRIA, WYO.

Jurassic	Drab shale	60
	Gray and pink shale	4

	Feet.	Inches.
Gypsum	8	
Light red shale	237	
Gypsum	7	
Red shale	58	
Gypsum	4	
Red shale with some gypsum	78	
Gypsum	12	
Red shale	88	
Purple limestone (Permian)	42	

XV. SEVEN MILES SOUTH OF SUNDANCE.

Drab sandy shales (Jurassic)	10+	
Chocolate-brown sandy shale	10+	
Streak of green clay	..	2
Chocolate-brown sandy shale with few green streaks	3	
Green clay		¼
Red sandy shale	3	
Green streak.		
Red sandy shale	1	
Green streak.		
Concealed.		

XVI. ONE MILE NORTHWEST OF SUNDANCE.

Covered to top.		
Red sandy shale.		
Impure gypsum	8	
Red sandy shale with network of gypsum veins	20	
Massive white gypsum	2	
Red sandy shale	5	
White gypsum	1	
(These two gypsum beds are connected by a vein of gypsum 2 inches thick with branches.)		
Chocolate-brown sandy shale	3	
White gypsum	1	
Red sandy shale with small specks of green clay	5	
Concealed		
Purple limestone (Permian).		

XVII. SEVEN AND ONE-QUARTER MILES NORTHWEST OF SUNDANCE.

Jurassic: Fissile drab-green shales	40	
Buff, friable sandstone	10	
Gray-green mudstone	6	
Thin-bedded buff clay sandstone	3	

		Feet.	Inches.
	Red sandy clay	20+	
	(In places the change from red to buff sediments is abrupt and plane. In others there is an intermingling of red and buff. In one place a pocket 2 inches deep and 4 inches wide in the red clay is filled with buff sandstone and a few rounded quartz pebbles varying in size from pin-heads to peas.)		

XVIII. TWO MILES NORTHWEST OF BEULAH.

Jurassic	Massive buff sandstone	5	
	Drab shale	..	2
	Light brown friable sandstone	15	
	Fissile green-drab shale	60	
	12 feet from bottom 1-inch bed of marl rich in Jurassic fossils.		
	White sandstone, with pebbles of smooth, rounded quartz from size of peas down	3	
	Undulating surface of contact.		
	Chocolate-brown sandy shale	20	
	Gray-drab clayey sandstone	3	
	Dark brick-red sandy shale	5	
	Gray-drab clay	..	2
	Brick-red sandy shale	35	
	Streak of green clay	..	2
	Red sandy shale with few streaks of green	30	
	Persistent bed of green clay	..	6
	Red sandy shale	25	
	Streak of green clay	..	2
	Red sandy shale	4	
	Green clay	..	5
	Red sandy shale	10	
	Green clay	..	1
	Red sandy shale	15	
	Green clay	..	2
	Red sandy shale, occasional streaks of green clay	50	
	Mottled gypsum (red clay admixture)	10	
	Red sandy shale.		
	Concealed.		
	Red sandy shale.		
	Massive white gypsum	4	
	Red sandy shale	10	
	White gypsum	2	
	Red sandy shale with veins of gypsum	15	
	Bedded gypsum.		

	Feet.	Inches
Purple limestone (Permian).		

XIX. NORTHEAST OF SPEARFISH; VALLEY NEXT EAST OF LOOKOUT PEAK.

Green shale (Jurassic)	10+	
Massive white gypsum	2	
Clayey sandstone	12	
Massive white gypsum	20	
Red sandy shale with few green streaks	50	
Gypsum	..	2
Red sandy shale	..	½
Green clay	..	½
Chocolate-brown sandy shale, few gypsum veins	20	
Green clay	..	1
Red sandy shale	2	
Gypsum	..	2
Red sandy shale	8	
More massive sandy shale	..	3
Chocolate-brown sandy shale with streaks of green	1	
Thin-bedded red sandy shale with specks of green	10	
Chocolate-brown sandy shale with network of gypsum veins paper-thick to 4 inches.		
Covered.		

XX. ONE AND ONE-HALF MILE WEST OF WHITEWOOD.

Section generally covered. Impure gypsum exposed toward the middle of red clays. Uniform dips of 28° and upper and lower contacts give thickness here of 450 feet for the Spearfish red beds.

These sections show that the upper red beds of the Black hills consist of about four hundred feet of red sandy shales with interstratified beds of gypsum. The shales are generally homogeneous in color, composition, and texture, but subordinate variations are caused by small green streaks and spots. The gypsum beds are irregularly distributed in lenses throughout the formation. Adjacent to the beds of gypsum frequently the red shales are traversed by interlacing gypsum veins. No fossils have been found in the Spearfish formation.

The red beds are characteristically red, the shade varying from chocolate-brown and dark red to light red; the usual tint is a uniform dark brick-red. The unaided eye sees in a hand

specimen a fine-textured arenaceous red shale, with occasional minute glistening particles of quartz and muscovite. The rock crumbles between the fingers to a fine powder, which with water can be readily molded; breathed upon, it gives the characteristic clay odor. The rock has no pronounced structure. It is coherent, yet easily friable, and breaks unevenly, with a tendency to a hackly fracture. Bedding planes are feebly developed and usually cannot be distinguished. Occasionally, though, when sand admixture becomes so prominent as to produce a clayey sandstone, thin flaky bedding planes become distinct.

Streaks and spots of green in the midst of the red shales form local variations. The green streaks seldom are continuous, but occur irregularly, often with uneven and wavy surfaces of contact with the red rocks. In places the green streaks follow small joint planes. The size of the streaks varies from a small fraction of an inch to three or four inches in thickness. The green spots are irregularly distributed and roughly spheroidal in shape; usually of about the diameter of a pin-head, they sometimes reach half an inch in diameter. In composition the green differs from the red shale by being poorer in iron and having a higher ratio of ferrous oxide. An analysis of adjacent green and red shale gave:

Green Shale.		Red Shale.	
Fe_2O_3	1.85 per cent.	Fe_2O_3	4.61 per cent.
FeO	1.04 "	FeO	1.24 "

Beds of gypsum occur at different horizons throughout the extent of the Spearfish formation, the greatest development being toward the middle of the series. Longitudinally no individual bed can be traced far. The thickness of the gypsum varies from a fraction of an inch to a maximum of about forty feet. Generally the gypsum is remarkably pure and the color a clear white. Occasionally admixtures of red clay produce a mottled appearance.

The following is an analysis of a sample of pure white gypsum collected near Cascade Springs:[1]

[1] By Mr. George Steiger.

SiO_2	0.10
Al_2O_3	0.12
CaO	32.44
MgO	0.33
H_2O	20.80
SO_3	45.45
CO_2	0.85
	100.09

Gypsum also occurs, forming interlacing networks of veins in the red sediments. The veins can be traced directly to adjacent beds of gypsum, and range from paper thinness to two or three inches. Frequently vein structure, crystals oriented perpendicular to the walls, occurs and sometimes two periods of formation of crystals are evident.

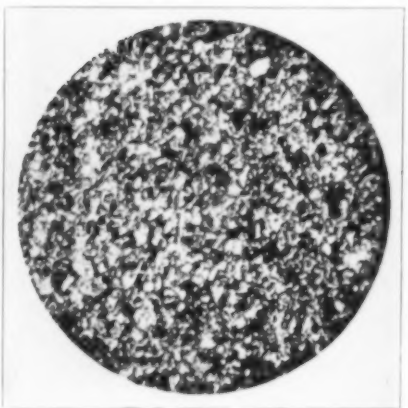
The red beds rest on the underlying purple limestone everywhere conformably. There is no indication of a period of exposure of the limestone to subaërial influences, but there is a sharp contrast in the character of the sediments. Massive limestone generally is followed abruptly by red shales; though in places—sections IV, V, and XVIII—gypsum immediately overlies the limestone.

In contrast to the uniformity of the lower contact, the transition from the upper red beds to the Jurassic is variable. The change does not occur in the red beds themselves, but rather marks the beginning of the Jurassic. The upper contact is locally an undulating, gently eroded surface; frequently, however, the contact is plane and apparently conformable. The upper contact is occasionally marked by pebbles of quartz varying in size from pin-heads to peas (section XVII). In one instance (section XIX) gypsum was found at the extreme top of the formation. The most pronounced change, though, is that of color. The uniform chocolate-brown shales of the upper Spearfish are succeeded by green shales or buff sandstones.

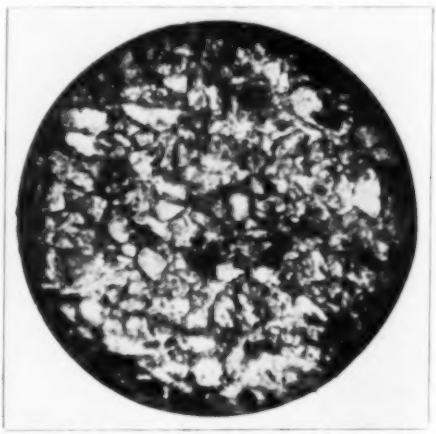
Microscopic characters.—Under the microscope the red shale is seen to be composed of minute white particles with irregular outlines coated by, and frequently including, an amorphous brown-red pigment. Quartz is the chief constituent, besides

which the white minerals are muscovite, calcite, magnesite, kaolin, gypsum, and feldspar. Some magnetite and ilmenite and occasional fragments of chlorite, are also present.

No systematic arrangement of the minerals occurs, the texture being characteristically sedimentary. The individuals are all minute; few are over 0.1^{mm} in cross-section, and the average is about 0.04^{mm}.



Magnified 50 diameters. ×56



Magnified 136 diameters. ×136

Microphotographs of thin sections of the spearfish red beds.

The quartz grains vary in size from 0.03 to 0.06^{mm} in cross-section. The particles are angular to subangular, seldom well-rounded. Some of the contours are so irregular, though smooth, as to suggest corrosion. Many of the quartz grains are perfectly clear and transparent, while others contain inclusions. Slender prisms of rutile are included in a few of the quartz grains, while others contain fluid inclusions. These do not contain red pigment and probably are original minerals derived from the disintegration of the parent rocks. Other quartz grains contain numerous inclusions of the red pigment and doubtless this quartz is secondary, being formed in the presence of iron oxide.

Muscovite is present in small clear rods, averaging 0.1 ^{mm} long

by 0.006^{mm} wide. Sericite occurs sparingly in irregular patches averaging 0.06 or 0.07^{mm} in cross-section and consisting of minute fibrous plates.

Carbonates occur scattered throughout the slides in rhombs that average about 0.03^{mm} in cross-section and in small irregular particles.

The presence of kaolin is suggested under the microscope by dull white flakes of irregular outline and of low refraction and birefringence. Bits of red pigment are frequently included. And the presence of kaolin is probable from chemical tests. The color was discharged from a piece of red clay by digestion in hydrochloric acid. The resulting gray powder was examined under the microscope, and white flakes of low double refraction were isolated, excluding quartz as far as possible. These flakes reacted for aluminum and water before the blowpipe.

Feldspars are very sparingly present. Some clouded fragments seem to be decomposed orthoclase. A few irregular areas of microperthite of fibrous appearance are also present. And very rarely bits of decomposed plagioclase occur.

Gypsum and dolomite, or magnesite, were not determined under the microscope, but their presence is shown by chemical analysis.

Amorphous red pigment is prominent in the slides. It irregularly coats and spots the minerals, and is included in some. The inclusions seem to be restricted to quartz and kaolin. This pigment constitutes the chief interstitial substance. It does not occur in continuous vein-like impregnations, nor does it form bands or local accumulations.

Analysis shows that the red pigment is iron oxide and that probably it is completely anhydrous. Sample No. 54, in which the complete analysis shows 2.84 per cent. of combined water, was treated with hot hydrochloric acid until all of the iron was dissolved. The residue was found to contain 1.90 per cent. of combined water, leaving 0.94 per cent. available for the hydrous minerals which hydrochloric acid would attack. Gypsum, and possibly an iron hydrate, are the only ones that the acid would decompose. Calculating the amount of gypsum from the

amount of SO_3, it is found that 4.8 per cent. of the rock is gypsum. This requires 1 per cent. of water, which practically is the amount available. No water, therefore, is left for combi nation with the iron. It is true this calculation is but an approximation, but it appears evident that the red pigment is either anhydrous or nearly so.

Chemical analysis.—Two specimens of the Spearfish formation were analyzed by Mr. George Steiger, of the U. S. Geological Survey, with the following results:

	Red Sandy Shale from East of Newcastle. No. 54.	Red Sandy Shale from East of Spearfish. No. 55.
SiO_2	56.20	58.32
TiO_2	0.77	0.48
Al_2O_3	11.50	8.59
Fe_2O_3	3.64	2.04
FeO	0.65	0.18
MnO	0.10	0.07
CaO	5.83	8.45
BaO	none	none
MgO	4.23	3.65
K_2O	3.74	2.71
Na_2O	0.98	0.72
Water 100 −	1.61	0.52
Water 100 +	2.84	1.40
P_2O_5	0.12	0 05
SO_3	2.26	0.43
CO_2	5.72	12.08
Cl	trace	strong trace
	100.19	99.69

The elements are so distributed that an exact determination of the relative abundance of the minerals in the rocks analyzed is impossible. Estimates based on the analyses and on the appearance under the microscope give the following approximate mineral composition of average red shale:

Quartz	41 per cent.
Muscovite	20 "
Kaolin	10 "
Calcite	9 "
Magnesite	8 "
Feldspars	5 "
Hematite	3 "
Gypsum	2 "
Magnetite, ilmenite, chlorite	2 "
	100

The analyses show traces of chlorine. Probably this is present as common salt, which, in spite of its solubility, may represent salt deposited in the red beds during their formation. No beds of rock salt have been found in the red beds of the Black hills, but a local accumulation is suggested by a salt spring in the red beds about three miles northeast of Cambria, Wyo. An analysis of this water by Mr. Steiger showed:

	Grams per Liter.
CaO	1.960
MgO	.448
K_2O	none
Na_2O	27.334
SO_3	3.556
Cl	31.479
Br	none
I	none
	64.787
Less O=Cl	7.094
	57.693

=51.582 grams of NaCl per liter.

DISCUSSION.

Red beds in general are well known to be colored by ferric hydrate or ferric oxide, but conditions that determine the formation and deposition of red pigment are various. Red beds have accumulated at different times and in different localities, under different conditions. This study was undertaken with the purpose of seeking evidence for the origin of the color of the red beds of the Black hills.

The history of these rocks is intimately connected with the history of the entire series of red beds of the central West, and a complete treatment of the subject is impossible without the accumulation of more facts, concerning the general geology of the Rocky mountains and adjacent regions, than are now known. Nevertheless the red beds of the Black hills constitute an isolated mass, and it is thought that an inquiry into the cause of their color, based on their description, will not be inappropriate.

Theories for the origin of the color of red beds.—One of the most obvious origins of red rocks is that they are formed by the dis-

integration and resedimentation of pre-existing red beds. This explanation, however, does not strike at the root of the matter, and in accounting for the color of such extensive masses of red beds as those in the western states is not applicable. For the rocks under consideration an explanation is demanded of the formation of original red beds. The following are the most important theories that have been advanced:

1. Water containing iron in solution percolating through rocks may have the iron precipitated as hydrate by contact with oxygen-bearing waters, or by other means. The hydrate thus formed subsequently may become dehydrated to the more stable red hydrate or to the anhydride. John W. Judd[1] in this way, explained the red color of the Northampton sands.

1 *a*. A variation of this method is the precipitation as iron carbonate of the iron contained in percolating waters by replacement of calcium carbonate with which the waters may come in contact. Oxidation may later convert the carbonate to the red iron oxide.[2] C. H. Smyth considers this one of the ways by which the red Clinton ores were formed.

2. Again, iron-bearing minerals in rocks on a land area may be decomposed by acidulated surface waters and the iron taken into solution as bicarbonate and transported to a body of water in which sediments are being deposited. Contact with air would convert the bicarbonate to ferric hydrate, which would be precipitated among the accumulating sediments.[3] Subsequent changes would dehydrate the iron precipitate to a stable red pigment. By this process bog iron ores are now accumulating. This explanation often has been appealed to in accounting for the color of red rocks. A. C. Ramsay[4] advocated such an origin for the color of the New Red sandstone. Also Henry Newton[5] applied this explanation, as his interpretation of the

[1] *Geological Magazine*, Vol. VI, p. 221.

[2] *Ibid.*, p. 487.

[3] Also some algæ have the power of precipitating ferric hydrate from certain iron solutions.—R. BRAUNS, *Chemische Mineralogie*, 1896, p. 383.

[4] *Quarterly Journal of the Geological Society*, Vol. XVII, p. 241.

[5] HENRY NEWTON, *Geology of the Black Hills of Dakota*, 1880, p. 138.

origin of the color of the red beds of the Black hills. In this way C. H. Smyth[1] accounts for the origin of some of the Clinton ores. And W. Spring[2] in his recent paper on the color of red beds accepts this theory and devotes his attention to details of how dehydration may take place after the iron has been precipitated as hydrate.

Another theory is that the color of red rocks may be caused by the sedimentation of a residual red soil. A. W. McKay[3] thus explained the color of the red sandstone of Nova Scotia. And I. C. Russell[4] has elaborated this theory and has applied it to the explanation of the color of the rocks of the Newark system.

3*a*. A variation in this process may occur when the iron in the soil, which furnishes the sediments of red beds, is not completely changed to the red ferric hydrate or to the anhydride previous to sedimentation. In such a case the soil would have a mottled color due to different stages of hydration of the disseminated iron compounds. Such mottled material may become uniformly red by dehydration of the disseminated iron subsequent to or during sedimentation.

J. D. Dana appealed to such a possibility in criticising Russell's widespread application of the theory of original deposition of red beds as such. Dana regarded conditions attending the consolidation of the rocks sufficient to cause the dehydration necessary to produce the uniform red. In the case of the rocks of the Newark system he considered the influence of the associated trap dykes, by virtue of their raising the temperature of interstitial water, potent to change to the anhydrous red oxide any limonite present about the individual rock particles.[5]

Dehydration may occur also during the process of sedimenta-

[1] C. H. SMYTH, *American Journal of Science*, Vol. XLIII (1892), p. 487.

[2] W. SPRING, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. XVII (1898), No. 2, p. 202.

[3] *Report British Assoc. Adv. Sci.*, Thirty-fifth Meeting (Birmingham, 1865), Part II, p. 67.

[4] *Bulletin 52, U. S. Geological Survey*, 1888.

[5] *American Journal of Science*, Vol. XXXIX (1890), p. 319.

tion. W. Spring[1] recently has shown that the presence of a salt in water produces on a hydrate an effect comparable to that of an elevation of temperature, and on this fact as a basis he would account for the color of red beds. Accepting the theory that red rocks are formed by the precipitation from solution of ferric hydrate about the individual particles of a deposit in an area of sedimentation, Spring maintains that red beds were formed in estuaries or in saline lakes, where the presence of dissolved salts would bring about the dehydration of the precipitated ferric hydrate necessary to produce the red pigment. The dehydrating effect of salt water is an important contribution, but whether the pigment of red beds was deposited from solution or as mechanical detritus is an independent subject, and one which must be settled by the study of any particular red formation.

Application of theories.—Let us now examine the evidence presented by the red beds of the Black hills, in connection with the requirements of these theories.

The first, providing for the deposition of the coloring matter by precipitation from percolating water subsequent to the formation of the rock, clearly is inapplicable. There are no available rocks which could supply sufficient iron in solution, neither is there any apparent reason why the pigment, if thus deposited, was limited to its present extent. Moreover, the uniform distribution of the coloring matter throughout the red beds in minute quantity, instead of in irregular or local accumulations, is difficult to explain by this theory. The coating of iron oxide about grains of quartz offers no suggestion that the pigment is a product of replacement. And the great extent of these red rocks seems to preclude the subsequent origin of the pigment.

The second theory—that the coating of pigment about the rock particles was precipitated from solution during sedimentation—is that which has been most generally appealed to in explanation of the color of red beds. The facts that such an

[1] W. SPRING, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. XVII, No. 2 (1898), p. 202.

explanation accounts for the red coating of the individual particles, and that it is difficult to disprove, are in its favor. Nevertheless, while it cannot be maintained that no ferric hydrate was precipitated from solution among the accumulating sediments under consideration, yet the evidence is that such was not the principal source of the pigment.

It will be shown presently that the climate during the sedimentation of the red beds probably was arid. Under such conditions vegetation would be scant, and surface waters would not be heavily charged with solvents. Conditions then were not specially favorable for rock decay, nor for the transportation of iron in solution to the area of deposition during red-bed time. Besides, if such were the origin of the pigment, local accumulations of it would be expected as in the case of those Clinton ores for which such an origin is accepted, and in the case of bog ores now forming. On the contrary, in none of the rocks examined microscopically does the thickness of the pigment amount to half a millimeter, and usually it is much thinner. The exact equilibrium required for the chemical precipitation of ferric hydrate to be just sufficient to coat each sedimentary particle, no more nor less, is extremely improbable.

Then there is the theory, emphasized by Russell, that red beds may be formed by the sedimentation of a residual red soil, and the evidence seems to be in favor of such an origin for the red beds of the Black hills.

It is a familiar fact that under suitable conditions rocks which contain iron-bearing minerals weather to a red clay. In the process of rock disintegration and decomposition the iron-bearing minerals alter easily. Ferrous iron—in biotite, hornblende, and pyroxene, for example—becomes oxidized and hydrated to limonite, which dehydrates and passes through stages corresponding to göthite and turgite, to the stable red hematite.[1] A late stage of residual soil, from a variety of parent rocks, consists of the stable minerals quartz, kaolin, and muscovite, traces of original rock constituents in various stages

[1] W. O. CROSBY, *American Geologist*, Vol. VIII (1891), p. 72; G. P. MERRILL, *Rocks, Rock Weathering and Soils*, 1897, p. 299.

of alteration, and red pigment indiscriminately distributed among the individual soil particles. Instances of residual red soils are numerous. Notable occurrences are: the soils of the Piedmont plateau of the southern Appalachians, the terra rossa of Europe, the laterite of India and the red soil of the valley of the Amazon.

Streams coursing over lands mantled with residual red soil transport it to areas of deposition, and thus tend to cause the sedimentation of red rocks. In many instances, however, in regions where red soils are abundant the red material washed from the land turns brown, and often greenish or bluish, before final deposition among accumulating sediments. For instance, in the Piedmont plateau region of the southern Appalachians red detritus in the streams generally becomes decolorized to the more somber tints of ferrous compounds, because of the deoxidizing influence of abundant decomposing organic matter in the water. But such destruction of the red color of detrital material so as to prevent the actual deposition and accumulation of red sediment is not universal. Thus enough of the red material brought down by the Amazon escapes deoxidation, so that vast deposits of red rocks are now accumulating along the coast of Brazil.[1] And it is probable that under more favorable conditions red rocks would accumulate more generally than now occurs. Such conditions would be the greater prevalence of areas covered with residual red soil and the absence of much organic matter in the waters concerned with the transportation and deposition of the red material.

In the case of the red beds of the Black hills it seems probable that unusually favorable conditions did exist both for the formation of a parent residual soil and for its accumulation as red sediment.

The geography of the Rocky mountain and adjacent regions in red-bed time[2] remains to be worked out. Still it is generally

[1] JOHN MURRAY, *Challenger, Reports Deep Sea Deposits*, 1891, p. 234.

[2] The age of the red beds of the Black hills, considered as an entire series, is not satisfactorily known, because no fossils have been found in the upper and lower formations. The intermediate limestone, however, carries fossils which indicate it to be Permian, but whether the lower red beds are in part Carboniferous or whether the upper are partly Triassic there is no direct evidence.

agreed that during the accumulation of the red beds of the central West a shallow mediterranean sea, whose outlines are very imperfectly known, existed west of the Mississippi and east of the great basin extending northward from Texas almost into Canada. In the midst of this sea the Rocky mountain province formed a group of islands.[1] Stratigraphic evidence renders it probable that different conditions prevailed simultaneously in different parts of the sea and that different conditions prevailed at different times in the same area. But insufficient facts have been accumulated to warrant a detailed statement of conditions that existed during the deposition of the red beds.

The Black hills area was covered by this body of water. The red beds there everywhere succeed the underlying Carboniferous rocks, with no signs of an interval of erosion. There is no evidence of thinning as the red beds approach the center of the hills, nor of off-shore conditions. Moreover, the dips carry these rocks over the highest points of the hills. The Black hills did not supply the sediments under consideration.

For the source of these red beds we must look to the land masses that were contiguous to the Black hills in red-bed times. These were an area of Algonkian rocks to the north and northeast, the lately uplifted Carboniferous limestone to the southeast, and the Rocky mountain area to the southwest and west.

That the limestone furnished sediments to the accumulating red beds in the Black hills cannot be denied, for the relatively insoluble constituents of limestone often form a residual red clay. Yet it is not likely that this was a prominent source. Of the areas named probably the limestone was the farthest away from the Black hills. Furthermore, the abundant quartz and mica in the red beds, and the presence of feldspar, magnetite, and ilmenite, point to a source from crystalline rocks rather than from limestone.

The extent of the Algonkian rock area is very indefinitely known, and it is doubtful whether this area contributed to the red beds of the Black hills. In this general region there was an

[1] S. F. EMMONS, *Bull. Geol. Soc. Amer.*, Vol. I (1890), p. 245; R. C. HILLS, *Proc. Colorado Scientific Soc.*, Vol. III (1888–90), p. 362.

extensive land area which may have been such from Cambrian down to Cretaceous time, but during red-bed deposition the respective limits of water and land are unknown. At Sioux Falls, S. D., there is an exposure of the Algonkian, the Sioux quartzite, which artesian-well borings show to have a considerable extent below the Cretaceous. The Sioux quartzite is a red rock which could have furnished red sediments. Microscopic study, however, renders it unlikely that this formation contributed to any considerable extent to the Spearfish formation. A characteristic feature of the Sioux quartzite is that it is composed of rounded quartz grains, the outlines of which are delicately traced by circlets of iron oxide imbedded in a matrix of interstitial silica crystallized in conformity with the nucleal quartz.[1] The red beds under consideration show no trace of this siliceous rim, which would be expected were the rocks derived from the Sioux quartzite.

The Rocky mountain region, however, was an available source of sediments for the red beds of the Black hills. During red-bed time this area was flanked by the deposition of red sediments whose constituents can be directly traced to such an origin.[2] And although the eastward extent of these red beds toward the Black hills is now deeply hidden by overlying rocks, so that actual stratigraphic connection has not been traced between the red beds contiguous to the Rocky mountains and those of the Black hills, yet such connection seems probable. Wells that have been put down deep enough east of the Rockies invariably have penetrated these red rocks. And the diminution in thickness of red-bed sediments from about three thousand feet adjacent to the mountains to five hundred feet in the Black hills, with an accompanying decrease in fineness of materials strongly suggests that the red beds of the Black hills are continuous with those of the eastern slope of the Rocky mountains.

The unusually favorable conditions, referred to above, for the

[1] S. W. BEYER, *Iowa Geol.*, Vol. VI (1897), p. 102.

[2] A. C. SPENCER, "Geology of the Rico Mountains," *Twenty-first Annual Report, U. S. Geological Survey* (1900), Part II, p. 68; G. K. GILBERT, *Pueblo Folio, U. S. Geological Survey*, 1897.

accumulation of a parent residual red soil and for its deposition as red sediment in the Black hills area were climatic.

It is generally believed that the Carboniferous climate in the present temperate zone was warm and moist. Under such influences the rocks of the Rocky mountain region, which general region is believed to have been land since the Cambrian,[1] were subjected to very favorable conditions for extensive decomposition and for the formation of a mantle of residual red soil. And because of the considerable decomposition the continued formation of red soil coincident with the removal of surface accumulations to supply red-bed sediments was facilitated.

It has been noted, however, that many regions which are now covered with residual red soil do not contribute red material to areas of sedimentation, because the red color is destroyed by deoxidation before or during deposition. But in the case of the red beds under consideration there is reason to believe that this deoxidizing influence was unimportant.

A relatively arid climate in many regions is known to have followed the warm and moist Carboniferous. That this was true in the red-bed region of the central West is testified to by the presence of beds of rock salt and gypsum. In the Black hills, though no beds of salt have been found in the red beds, yet the salt spring near Cambria suggests a local deposit; and interbedded gypsum is abundant.

There can be little doubt that the gypsum of these red beds was accumulated by precipitation from concentrated water containing calcium sulphate in solution. The "bar theory" of Ochsenius[2] clears the difficulty of conceiving how thick beds of chemically precipitated matter can be accumulated; and all the field relations of the gypsum point to such an origin. There is no indication that the gypsum is the result of the action of sulphuric acid on limestone. The bedded character of the gypsum interstratified with detrital sediments, the general occurrence of the gypsum in lenses, the frequent presence of layers of red sand and clay in beds of impure gypsum and of thin layers of

[1] EMMONS AND HILLS, *op. cit.*

[2] *Zeitschrift für praktische Geologie*, 1893, p. 189.

gypsum among the red sediments, besides the presence of gypsum disseminated throughout the red sediments, as shown by the rock analyses, lead to the conclusion that the gypsum was deposited as a chemical precipitate contemporaneously with the detrital sediments. Such an origin demands a somewhat arid climate.[1]

Now, an arid climate, sufficient to cause the precipitation of beds of gypsum tends to cause the preservation of the color of red sediments. Being unfavorable for the existence of abundant life in inland waters, such a climate minimizes the prevalence of deoxidizing influences incident to the presence of organisms. In this connection the general absence of fossils in the red beds is noteworthy.

With such favorable conditions for the accumulation of a red soil and for its deposition as the red beds of the Black hills let us look now for direct evidence bearing on the origin of the color furnished by the composition of the rocks under consideration.

The chemical composition of the red beds of the Black hills is essentially that of a residual red clay, notwithstanding the abundance of carbonates and sulphates. These unusual constituents were not of detrital origin, but were caused by conditions of sedimentation.

The gypsum already has been referred to, and considering the general paucity of life in the water in which these red beds were accumulated and the salinity of this water, the calcium and magnesium carbonates, which are disseminated throughout the red beds, appear to have been formed as chemical precipitates instead of having had a more direct organic origin. The presence of crystals of these carbonates means that they were deposited from solution. Their widespread and uniform dissemination, and the absence of veins and local accumulations, implies original deposition with the detrital sediments rather than subsequent introduction from percolating water. A secondary derivation from decomposition subsequent to sedimentation is

[1] The succession of a genial Carboniferous climate by post-Carboniferous arid conditions is emphasized by CHAMBERLIN, JOUR. GEOL., Vol. V, p. 678.

not borne out by the presence of associated, partly decomposed minerals.

Excluding these adventitious constituents, the analyses show the red beds of the Black hills to be composed essentially of silica, alumina, ferric oxide, potash, and water. These are characteristic components of residual soils, the corresponding mineralogical composition being the stable species, quartz, muscovite, kaolin, and the red pigment with occasional bits of decomposed feldspar.

The result of microscopic examination also shows the similarity of these red beds with residual red clay. Some of the quartz grains have intricate contours, as if etched by alkalies derived from decomposing feldspar. The disposition of the pigment as a coating to the individual rock particles is like that in residual red soils. And the inclusion of the red pigment in secondary quartz and kaolin is significant.

This inclusion implies the formation of the including minerals in the presence of the red pigment. It is not probable that these minerals were formed in the area of deposition when the sediments were accumulating so as to receive inclusions of iron precipitated from solution; nor is it a likely assumption that much decomposition took place subsequent to the formation of the red beds, and that the secondary minerals received inclusions of iron from percolating solutions. There is but little undecomposed material in the red beds, whereas considerable remains would be expected did alteration take place after sedimentation. The composition of the red beds is essentially of stable minerals, but some of the quartz and all the kaolin are products derived from decomposition. On the land area where the parent red soil of the red beds was accumulating, it is to be expected that in the intimate association of the constituents, iron oxide became included in the secondary minerals that were formed as decomposition products. Such inclusions are common in residual red clay in the District of Columbia.

It seems probable therefore that the dominant factor in the production of the color of the red beds of the Black hills was a residual red soil on the land mass which supplied the sediments.

But inasmuch as favorable conditions for dehydration existed in the area of deposition, it must not be asserted that the color of the red beds of the Black hills was entirely formed in the parent soil, and that none of the color was formed during sedimentation.

W. O. Crosby has called attention to the effect of exposure of iron-bearing sediments in shallow-water areas of deposition upon the production of red pigment.[1] This action depends on the dehydration of hydrated iron compounds and is a further operation of the influences which have been emphasized as the effective cause in the production of a residual red soil.

Another factor in the production of red pigment from hydrated iron compounds is the dehydrating effect of salt water discovered by W. Spring.[2] Because the red beds of the Black hills were deposited in concentrated waters, this influence operated and may have been important.

The presumption is, however, under the favorable climatic conditions and from analogy with the homogeneous red tint of many present residual red soils, that before the soil particles were actually deposited they had become completely red. But the possibility of these two causes having acted must not be forgotten. And, too, the fact must be borne in mind that the dehydration of ferric hydrates tends to go on under ordinary conditions without any unusual cause.[3] So that it is unnecessary to assume the action of further dehydrating agencies than those operating on the land which supplied the residual soil.

Whether a change in the pigment occurred subsequent to deposition, as suggested by Dana,[4] should be considered, inasmuch as the Black hills have been subjected to igneous intrusions. There are, however, in the central west province, red beds — similar to those in the Black hills and apparently genetically connected with them — which are not associated with

[1] W. O. CROSBY, *Proc. Boston Soc. Nat. Hist.*, Vol. XXIII (1888), p. 509.

[2] *Op. cit.*

[3] This has been repeatedly demonstrated by experiment: WITTSTEIN, *Vierteljahresschrift für Pharmacie*, Vol. I (1852), p. 275; DAVIES, *Jour. Chem. Soc. of London*, Vol. XIX (1866), p. 69; VAN BEMMELN, *Recueil des travaux chimiques des Pays-Bas et de la Belgique*, Vol. VII (1888), p. 106.

[4] *Op. cit.*

igneous rocks. Moreover, if the igneous rocks of the Black hills exerted a dehydrating influence sufficient to change the red beds from a possibly mottled previous condition to their present uniform color, such influence surely would have dehydrated the varicolored iron pigments in the underlying Carboniferous sandstone. This, however, did not occur, and the suggestion of Dana is not applicable in the Black hills.

Green variations.—The occurrence of green variations in red beds has caused some[1] discussion. In the case of true green beds among sediments derived in general from red soils, it seems likely that such green beds were either deposited from a locally different source than the red material, or that they represent red sediments which were deoxidized in the area of deposition. But small green spots and streaks, which constitute the general occurrence of green material in the Spearfish formation, can best be explained by considering them to have been developed subsequent to deposition.

These variations can be accounted for by the influence of occasional bits of organic matter present in the sediments. Such decomposing organisms reduced the ferric iron of the red pigment to a soluble form that was removed in solution, and green spots and streaks remained. In spite of the lack of more evidence of organic remains in the red beds, these green variations are difficult to explain in any other way. The irregular distribution of the green patches, their occasionally following cracks in the rocks, and their similarity in composition to the adjacent red clay, from which they differ only in containing less iron, point to this explanation.

GEORGE B. RICHARDSON.

[1] GEORGE MAW, *Quarterly Journal Geological Society of London*, Vol. XXIV, p. 351; T. N. DALE AND W. T. HILDEBRAND, *Nineteenth Annual Report United States Geological Survey*, Part III, p. 255.

NEW OR LITTLE-KNOWN VERTEBRATES FROM THE PERMIAN OF TEXAS.

In 1880 Cope gave the first description and figure of the scapula of *Eryops*.[1] He had at the time only the lower portion of the scapula with the co-ossified coracoid, bearing the cotylus for the humerus. Later, in 1888,[2] he published a figure of the shoulder-girdle with the clavicles and interclavicle in place. As in the first specimen, the distal end of the scapula was missing, but there was a small fragment of a distinct bone joining the upper edge of the scapula, which he regarded as possibly a portion of the scapula, but was uncertain as to its exact position. In 1899, Broili[3] described a skeleton of *Eryops* in which he identified the fragment mentioned in Cope's description as the epiclavicle or cleithrum. In 1898[4] the author mentioned the presence of a cleithrum on the distal end of a scapula which was regarded at the time as reptilian. The element is indicated by a small fragment of the bone, which is attached by strong rugose grooves and ridges to the scapula. The specimen (No. 76) of the collection of the University of Chicago, probably belongs in the genus *Eryops*, but to a species distinct from *megacephalus*. It is shown in Fig. 1. It is the third scapula described below.

In looking over the collection of the Chicago University I find a nearly perfect scapula of *Eryops* (No. 182), with a complete cleithrum in position. The bones have been badly broken, but are little distorted and differ so much from the type species that I refer them to a new species under the name *Eryops latus*. The general outline of the bones is shown in Fig. 2. The scapula differs from that of *Eryops megacephalus* in the relatively greater breadth of the coracoidal region and the straightness of the antero-internal edge. The cleithrum is a queerly shaped bone;

[1] *Proc. Am. Phil. Soc.*, Vol. XIX, p. 51, 1880.

[2] *Trans. Am. Phil. Soc.*, Vol. XVI, p. 362, 1888.

[3] *Paleontographica*, Vol. XLVI, p. 61, 1899.

[4] *Am. Nat.*, Vol. XXXII, p. 70, 1898.

the posterior end is thin and greatly expanded so that it overlaps the upper portion of the distal end of the scapula and is closely applied to it as a thin scale; it is convex outwardly. The anterior two-thirds of the bone is rounded and rod-like. It lies close to the upper edge of the scapula, but is to be described as applied to it rather than being articulated with it, for where the bone is broken away the edge of the scapula is smooth and complete. The edges of the rod-like portion of the cleithrum were evidently extended as narrow and very thin wings. The anterior edge is sharp and marked with rugosities where it joined the clavicle, as indicated in Cope's figure. Broken fragments of the clavicle were found with the scapula and show that the anterior face of the proximal portion was marked with very deep and rugose striations and ridges. The evidence of the cleithrum afforded by this specimen makes our knowledge of the shoulder-girdle of *Eryops* complete.

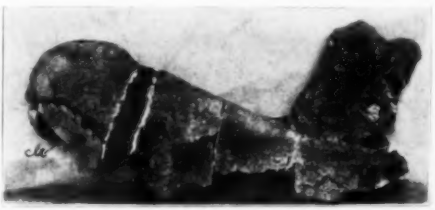


FIG. 1.—Scapula of *Eryops sf.*, showing attachment of cleithrum. *clt.* Left side.

MEASUREMENTS OF E. LATUS.

Breadth across epicoracoid region	.182 m
Breadth opposite center of face for humerus	.079
Width of scapula at middle	.073
Greatest length scapula	.371
Greatest length of cleithrum	.237

In the process of investigating this scapula it becomes very evident that a close similarity existed, superficially, between the scapula of *Eryops* and that of the Pelycosaurian reptiles, and this led to a search for points that might be used in their separation. Baur says that there is no ossified coracoid in the Stegocephali and that the cleithrum does not occur in the reptiles, *Parciasaurus* excepted. Williston mentions the presence of scapula, coracoid and pre[epi]coracoid in *Eryops*, but says that they are so closely united that the sutures are indistinguishable.

Broili describes a scapula and coracoid in the same genus, but evidently regards as coracoid the bone usually described as epicoracoid, leaving the part here described as coracoid absent or cartilaginous. Cope speaks of the coracoid as distinctly recognizable, but figures no suture and describes the epicoracoid as probably present but not recognizable. There thus seems to be considerable difference of opinion regarding the presence of the coracoid. From considerations cited below it seems to me that the coracoid was cartilaginous, but if so the anterior end of the scapula assumed a strikingly similar form to the coracoid of the reptiles, sheltering the whole of the humeral cotylus, which in the reptiles is shared between the coracoid and scapula.

FIG. 2.—Scapula, epicoracoid, and epiclavicle of *Eryops latus*, showing the complete cleithrum. *clt.* Left side.

In *Eryops* the antero-internal edge of the bone is thickened and shows the previous attachment of a thick plate of cartilage. This mark of cartilaginous attachment extends around the anterior end of the bone from the anterior end of the face for the humerus to about the end of the anterior fourth of the upper edge, where it terminates in a small but decided angle at the point where the clavicle touched the scapula. Both the cartilaginous edge and the angulation seem to be diagnostic characters of importance, for in the reptiles they are absent. The coracoid of the Pelycosaurs has a sharp beak-like process and the anterior edge is free from cartilage. The edge of the epicoracoid is thin and the cartilage was either absent or small. In the Pelycosaurs the coracoid is always distinctly separated from the scapula by suture, and is apt to be a separate fragment in the specimen. In *Eryops*, the cotylus for the humerus is deeper and the anterior and pos-

terior edges are raised so that the cavity is almost a semicircle; in the reptiles the cavity is shallower and more widely open. The articular face of the cotylus differs in the two. In *Eryops* it is about equal in width at the two ends, but is abruptly wider a little anterior to the middle point; in the reptiles the two ends are the wider and the middle portion is of equal width.

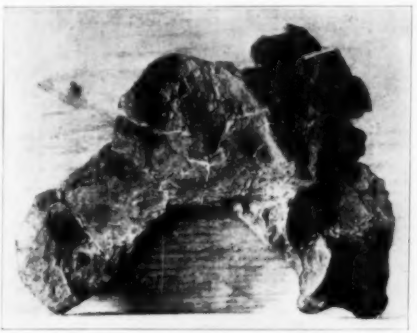


FIG. 3.—Scapula, coracoid, and epicoracoid of a diadectid reptile. Right side.

A second scapula, No. 186 of the collection, differs from any heretofore seen by me in its shortness and relatively great width. As it has a free coracoid, no trace of an episcapula, and a very narrow face for cartilage on the anterior edge of the epicoracoid, it is regarded as reptilian, and its robust character shows that it belongs to some genus of the Diadectidae. It so probably belongs to a species already named that I have given it no new name here, leaving its identification to future discoveries. Fig. 3 gives the best idea of its general form. Notable, in comparison with the other scapula, is the great width of the anterior edge and the great width of the median portion, which is as wide as any part of the anterior edge. At its posterior two-thirds the bone narrows rapidly and terminates in a thin blade, which shows the marks of cartilaginous attachment on its distal and upper edges. There are two foramina in the bone in much the same position as in *Eryops*, and both open into a large pit on the inner surface of the bone. The anterior foramen opens on the outer face in a deep pit located just anterior to the prominent edge of the upper portion of the humeral cotylus, instead of somewhat farther out upon the epicoracoid, as in *Eryops*. The scapular and epicoracoidal portions meet at the suture in an angle of about 80°, as shown in the figure by the lighting of the photograph. Just

distad to the cotylus in all the scapulae there is a triangular space into which opens the second of the two foramina; this portion of the bone is thickened and its edge is rounded. In *Eryops* this triangular space is marked by a deep pit and the foramen pierces the bottom of it. In the scapula under description the space is flat and the foramen enters at the apex of the triangle, which is toward the distal end of the bone. The space is marked with a V-shaped rugose line near its anterior end; no such line occurs in *Eryops*.

FIG. 4.—Scapula, coracoid, and epicoracoid of *Embolophorus dollovianus*. With clavicle in position. Right side.

Length of scapula No. 186	.257 m
Width at cotylus for humerus	.190
Width of distal end	.066

The third of the scapulae, No. 76, while distinctly amphibian, presents many reptilian characters. As shown in Fig. 4, it has a distinct cleithrum firmly attached to the distal end of the scapula, and there is no evidence of a bony coracoid; on the other hand there is no evidence of cartilaginous attachment on the coracoidal and epicoracoidal edges. The anterior foramen is located in a pit on the anterior edge of the upper extremity of the cotylus, and in this respect is much more similar to the reptiles than to the amphibians. The triangular space distad to the cotylus is filled and marked by a V-shaped rugosity, as in the Diadectid scapula.

FIG. 5.—Dorsal spine of *Zatrachys crucifer*. From behind.

In *Dimetrodon* and *Embolophorus* the anterior foramen opens close to the strongly projecting upper edge of the cotylus;

there is no triangular area, and the posterior foramen opens on the summit of a ridge directly posterior to the elevated edge of the cotylus. Fig. 4 shows the scapula of the right side of *Embolophorus dollovianus*, with the almost perfect clavicle in its normal position.

At this point may be noted a peculiar relation which exists between the scapulae of the American and the African reptiles. In Clepsydropsidae there is no trace of the attachment of the clavicle to the scapulae, except in the problematical facet figured by Cope as possibly forming an articulation for the clavicle. In the Dicynodonts and the Theriodonts there is a distinct process on the scapulae for the clavicle, and this exists even in *Pareiasaurus* where the epiclavicle is still present. In *Cynognathus* this process has developed into a strong scapular spine which occupies the upper edge of the scapula nearly in the same position as is the scapular spine of the Monotremes.

Zatrachys crucifer. sp. nov.

A single neural spine, No. 171 of the Chicago collection, indicates a new form which I have referred to a new species of the genus *Zatrachys* Cope. As shown in Fig. 5, the spine has a cruciform shape with a sharp upper portion and short lateral processes. The posterior zygapophyses are preserved and are relatively small. The upper faces of the lateral processes and the apex of the spine are pitted by a deeply marked rugosity so that the whole upper surface of the spine is excavated by deep pits of a size and depth seen before only in the larger amphibians, *Eryops*, and *Cricotus*. The lower surfaces of the later processes and the sides of the base of the spine are smooth. The anterior and posterior edges of the apex are free from the deep pits and are marked by a narrow space of striations showing that the spine was overlapped by the edges of some other element; it is evident from the shape of the spine that this could not have been the edges of the adjacent spine, but must have been an extra element intercalated between the spines, probably one of the dermal ossifications such as occur along the spine of *Pareiasaurus*. The nearest approach to this condition is found in the

rugose expanded apices of *Zatrachys apicalis* Cope, and so I have referred this specimen to that genus until further information may be obtained. Fig. 5. The fragment is .054^{m} in height and .058^{m} across the lateral processes.

DIADECTIDAE.

The family Diadectidae is known so far from the skull, teeth, vertebrae, pelvis, clavicle, and interclavicle; to this we may add the scapulae, if the specimen described above belongs, as assumed, to this family. The separation of genera and species has been done almost entirely upon the characters of the teeth and skull, so that it has been impossible to determine accurately the position of isolated bones. A specimen in the Chicago collection (No. 62) makes it possible to add a description of the caudal vertebrae, some of the bones of the limb and foot, and especially the presence of an unsuspected structure, *i. e.*, dermal plates overlying the ribs and corresponding to them in number. This last structure is shown in two separate fragments; the largest shows five ribs in place and the plates covering them. It is impossible to say which side the fragment is from. The ribs are quite stout and show a large medullary cavity. The plates are large and thin. Their edges are broken away so that their size cannot be determined. The plates lie one over the other like shingles. The plate at one end has the end broken and turned down. Near this is a separate fragment which may be either a portion broken off from the edge of the plate or a distinct marginal plate. The approximate width of each of the plates is .033^{m} and the length of the fragment is about .160^{m}.

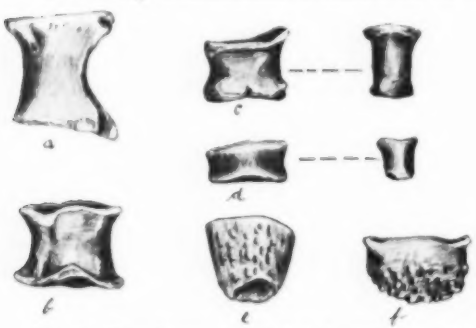


FIG. 6.—Foot bones of a diadected reptile; *a* and *b* metacarpals (?); *c*, *d*, *e*, phalanges found united; *f*, another terminal phalange.

The limb bones consist of the lower end of a humerus, two bones of the fore limb and a fragment of the carpus (?) with the distal end of a bone of the forearm (?) attached. Besides these there are several phalanges, some in connected series. The phalanges and metacarpals (?) are remarkably short and strong and the terminal phalange was covered with a very stout claw bearing out the suggestion made by Cope that the animals were fossorial in habit. Unfortunately there are not more than three phalanges united in any one fragment, and there are six terminal phalanges altogether, so that it is impossible to state the exact number of phalanges in the digits, but it is probable that the usual reptilian formula was present. The phalanges are shown in Fig. 6.

FIGS. 7.—Lower end of humerus of a diadected reptile. Left side.

FIGS. 8 and 9.—Limb bones of same specimen as Figs. 6 and 7.

The bones of the limb are stout and short. The humerus is very imperfect, only the lower portion being preserved, but it indicates a very stout bone, and the lower end is strikingly similar to that of *Eryops;* the head for the radius is very large and is located almost entirely on the anterior side of the bone; just posterior to it is a strong descending process that reaches below the lower end of the bone. Fig. 7. There is a distinct ectepicondylar process on the outer side of the bone. There is no entepicondylar foramen visible, but the bone is broken below where this should appear. The two other limb bones are shown in Figs. 8 and 9.

FIG. 10.—Caudal vertebræ from same specimen as that shown in Figs. 6–9.

The caudal vertebræ differ markedly from the typical dorsals. The centra are as high as long and the neural spine is as high as the length of the centrum. The centrum is not broader than long and is deeply amphicœlous. There are well-developed anterior and posterior zygapophyses, but no trace of zygosphene or zygantrum. The lower side of the vertebræ is marked by the exceptionally strong and elongated chevron bones; they are attached between two adjacent vertebræ, and there is a strong face on the lower edge of the posterior surface of the preceding vertebra for the attachment of the head of the chevron. The caudals with chevrons are shown in Fig. 10.

MEASUREMENTS.

Length of the longest limb bone	.106[m]
Width of the complete end	.065
Length of the shortest limb bone	.087
Width of its widest end	.047
Width of its shortest end	.036
Length of three caudals	.061
Height of the first from the base of centrum to top of spine	.044
Horizontal diameter of centrum of first	.012
Vertical diameter of centrum of first	.019
Length of a complete chevron	.031

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NOTES ON THE GEOLOGY OF MOUNT KEARSARGE, NEW HAMPSHIRE.

MOUNT KEARSARGE[1] or Pequawket is a mountain of medium height in the southern part of the White mountains of New Hampshire. It is situated a few miles north of North Conway, partly in the town of Bartlett and partly in the town of Chatham. It rises 3,260 feet above the sea, and 2,700[2] feet above the neighboring valley of the Saco river; and includes, as a spur on its southwestern slope, Mount Bartlett. The latter rises 2,630 feet above the sea. These two mountains cannot be separated in a geological study of this mountain mass.

The rock making up the base of these mountains is what Hitchcock has called the Conway granite. On the south slope of Kearsarge this granite is found up to the level of 1,300 feet; on the southwest and west slopes of Bartlett, up to 1,000 or 1,100 feet; on the northwest slope of Kearsarge, up to 1,800 feet; and on the northeast slope of Kearsarge, up to the 2,500 foot level.[3] This granite also makes up the base of Moat mountain, on the opposite side of the Saco river, and is found on the north slope of this mountain in the course of Cedar brook up to the 900 foot level. It is found, in addition, over a broad area around, and is quarried in a number of places. The large quarry in the side of the mountain at Redstone, three miles southeast of North Conway, is in this granite.

The Conway granite[4] is reddish in color, is coarse in crystalline texture, is without foliation or granulation, and is very massive, being cut by few joints either vertically or horizontally. In the quarry at Redstone the distance between the joints is very noticeable. The first joint from the surface, when I was there,

[1] Geological section of this mountain is represented on the second sheet of the geological map of New Hampshire in the atlas accompanying *Geology of New Hampshire*.

[2] Taken from the topographic map of the *U. S. Geol. Surv.*

[3] Determined by means of an aneroid.

[4] Described in *Geology of New Hampshire*, Vol. II, p. 142.

was three feet down; the second, four or five feet below the first; and the third, twenty-five feet or more below the second. In working the rock it is necessary to cut the rock horizontally as well as vertically. The size of the blocks that may be taken out is limited only by the strength of the derricks. The few joints seen were parallel with the side of the mountain, indicating, as the mountain has been produced by erosion, that these joints are due to causes acting since the formation of the mountain.

The orthoclase of the Conway granite is of a reddish tint, and is so abundant as to give its color to the rock. This feldspar occurs in coarse particles an inch or so through, which frequently show Carlsbad twinning. These particles do not present the definite outline of crystals, and do not give a porphyritic appearance. In addition, there is a white feldspar much less abundant, and distributed irregularly, and also in irregularly shaped cleavage particles much smaller than those of the orthoclase. This is a triclinic feldspar, and is twinned according to the albite law.

The quartz is generally distributed in irregular granular masses varying in size from one-half inch to one inch through. It is of a decided smoky-gray color, and, in contrast with the red feldspar, gives a mottled appearance to the rock surface. The quartz masses frequently inclose grains of both the red and white feldspar. There is also quartz distributed in finer particles inclosed in the orthoclase, and entirely separated from the coarser granular masses. These second quartz particles are generally anhedra, but somewhat frequently show distinctly the angles and faces of crystals. This clearly indicates that not all of the quartz crystallized last in this granite, but that a part crystallized before, or along with, the feldspar.

The biotite of the granite is small in quantity, of full black color, and occurs in small, foliated particles rarely more than one-sixteenth of an inch in length or width. It is generally distributed with the coarser granular quartz masses, though some finer scales are inclosed in the feldspar.

In addition the rocks contain a little magnetite.

The specific gravity of the granite is 2.624, and its composition is shown in the following analysis:[1]

SiO_2	73.01
Al_2O_3	13.73
Fe_2O_3	0.44
FeO	1.48
MnO	0.09
CaO	0.94
MgO	0.01
K_2O	5.62
Na_2O	3.50
Loss at 110°C	.05
Loss over blast	.18
	99.05

The weathering of this granite is very characteristic. Every bowlder in the fields has partly or entirely crumbled to a barren ring of gravelly débris. This débris consists of loose, angular, rusty particles varying in size from those an inch through down to fine powder. The particles consist, as far as can be seen, of orthoclase and quartz. The former, during the disintegration, loses its luster and bright flesh-red color, and assumes a dirty rusty color; it does not, however, become covered with a fine powdery coating of kaolin, but is divided into little cleavage blocks by many cracks along the cleavage planes. The angular quartz grains are thrown out by the breaking of the feldspar, and the anhedra and quartz crystals may be found among the particles of the crumbling rock.

The mica is generally decayed, and has changed from a black to a brownish, bronzy, or brassy color. Secondary epidote is frequently seen with the decaying biotite. The triclinic feldspar is rarely seen in the disintegrated particles of this granite.

The analysis of a fair sample of some of the coarser of these particles afforded:

[1] Other determinations were not made. The methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were closely followed.

SiO_2	70.18
Al_2O_3	15.13
Fe_2O_3	00.68
FeO	1.54
MnO	0.13
CaO	0.84
Na_2O	2.67
K_2O	8.93
Loss at 110°C.	0.10
Loss over blast	0.22
	100.42

The disintegration of the rock is both chemical and mechanical. The triclinic feldspar and the mica are the first minerals to decay. The frost and mechanical agents then act between the minerals and along the planes of cleavage in the orthoclase, prying apart the minerals and crumbling the rock. The coarseness of the texture probably materially aids these agents in their work. The comparatively rapid disintegration of this granite does not specially recommend it as a building stone, though the somewhat numerous quarries in it indicate a considerable use of it for that purpose.

Within the Conway granite are found inclusions of an earlier granite. The rock of these inclusions is of a light gray color, of a medium-fine, granular texture, and is perfectly massive, without banding, foliation, or parallel arrangement of the minerals. The feldspar is white and glassy, and is partly triclinic. The quartz is finely granular and slightly smoky, and forms with the feldspar an intimate mixture. The black biotite is so abundant as to give a gray color to the whole rock.

Generally, on the different sides of Kearsarge, as well as on the sides of Bartlett, there is found above the Conway granite a granite-porphyry. In this the feldspar phenocrysts measure about one-fourth inch through. These feldspars are orthoclase, and are in part reddish throughout, and in part reddish on the borders with a white center. The outline of the phenocrysts is generally rounded rather than angular. The quartz, of a smoky color, occurs in part in distinct particles, one-sixteenth to one-eighth inch through, sometimes showing crystal forms. The

groundmass of the granite-porphyry consists of a fine granular mixture of reddish feldspar, smoky quartz, and black mica, together with, in some places, fine black hornblende and a little magnetite. Iron pyrites is occasionally seen.

The granite-porphyry does not weather and crumble so rapidly as does the Conway granite; neither does it form any such

FIG. 1.—Just left of the center of the picture is shown an inclusion of finely-grained gray granite in the coarse Conway granite. Inclusion 3–4 feet in diameter.

gravelly débris. It is but a few feet, fifty or so, in thickness on the south side of Kearsarge, and on some sides of the mountain was not observed at all, either because entirely absent or because covered. There is a like granite-porphyry in the bed of Cedar brook on the north side of Moat mountain, where there is exposed an excellent section.

Above this granite-porphyry in Mount Kearsarge, or above the Conway granite where the porphyry does not occur, the rock is a quartz-porphyry. This latter rock varies in color from a

red to a dark gray. The gray is the prevailing color, while red is more characteristic of the porphyry nearer the granite. The porphyry is massive and without foliation, and is cut by many joints into quite small, irregular, sharply angular blocks.

The quartz is very noticeable. It is smoky in hue, and occurs generally in distinct rounded anhedra one-sixteenth to one-eighth inch through. Now and then among these anhedra may be found a bipyramidal quartz crystal. On the east slope of the mountain, at about the 2,000 foot level, was found a gray quartz-porphyry abounding in quartz crystals, so that every broken surface and every weathered surface presented many of the little projecting pyramids, and the six-sided tapering cavities from which crystals had been broken. The porphyry abounding in quartz crystals is at a considerable distance from the granite beneath.

In the porphyritic phases having the finer-grained groundmass there are orthoclase phenocrysts, but in the coarser-grained varieties the intercrystallizing feldspars constitute the groundmass about the quartz particles with only a trace of the finely grained mixture.

Different specimens of the porphyry afforded on analysis the following results:[1]

	I.	II.
SiO_2	78.37	75.38
Al_2O_3	10.85	11.85
Fe_2O_3	1.33	1.78
FeO	0.44	0.88
MnO	0.06	0.10
CaO	0.40	0.33
MgO	0.00	0.00
Na_2O	2.68	3.68
K_2O	5.52	5.37
Loss at 110° C.	0.04	0.15
Loss at red heat	0.59	0.50
	100.28	100.02

[1] Other determinations were not made. Methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were carefully followed.

	III.	IV.
SiO_2	72.25	73.33
Al_2O_3	13.40	12.95
Fe_2O_3	1.10	0.98
FeO	1.53	1.66
MnO	0.11	0.13
CaO	0.74	0.98
MgO	0.00	0.00
Na_2O	4.27	3.46
K_2O	5.56	5.61
Loss at 110°C.	0.10	0.11
Loss at red heat	0.31	0.30
	99.37	99.51

I. Coarse quartz-porphyry, red in color, finely granular groundmass small in quantity and distributed among the coarser red feldspars; from the 1,350 foot elevation near the phyllite, on south slope of Mount Kearsarge. Specific gravity 2.614.

II. Bluish-gray quartz-porphyry, groundmass fine, of bluish-gray color, inclosing anhedra of quartz and phenocrysts of red feldspar. From 1,550 foot elevation, south slope, Mount Kearsarge, near phyllite. Specific gravity 2.62.

III. Dark gray quartz-porphyry; from top of Mount Kearsarge. Specific gravity 2.643.

IV. Dark gray quartz-porphyry, abounding in quartz crystals; from eastern slope at about 2,000 foot elevation. Specific gravity 2.64.

With these analyses of the porphyry, together with that of the Conway granite before us, we may consider the relation of the porphyry to the granite. It has been pointed out that there is generally in Mount Kearsarge and Mount Bartlett between the porphyry and granite a granite-porphyry. The best place to study the relation of these rocks in Mount Kearsarge is on the southern slope in the trail. Though the rock surface is not exposed as much as might be desired, nevertheless it is possible to observe a reasonably well defined gradation from Conway granite into the granite-porphyry, and then from the latter into the quartz-porphyry.

But this gradation may be more clearly and easily seen in the bed of Cedar brook in the lower part of Moat mountain.

Beginning at the 900 foot contour in the brook bed, there appears what is clearly the Conway granite, though possibly a

little finer in texture than the granite farther down the stream. Ascending the brook bed a few feet, the rock begins to be slightly porphyritic, and at the same time contains less biotite. There may be distinguished in this phase the beginning of a finer-grained groundmass. Then 150 feet up the brook bed, only 20 feet or so higher vertically, the surface of the ledge being exposed all the way, may be found the granite-porphyry. Its resemblance to the preceding is very close, yet the fine groundmass of a light gray color is clearly defined, inclosing the distinct feldspars, one-half to three-fourths inch through, and the blebs of smoky quartz, together with the black foliated masses, one-eighth inch or less through, of biotite. The biotite is noticeably less in quantity than in the granite beneath.

This gradual variation and gradation may be easily traced until, at the 1,100 foot level, the rock is a quartz-porphyry, the biotite appearing not at all, or now and then only in traces, and the rock, aside from this, identical with the quartz-porphyry higher in the mountain.

The quartz-porphyry of these mountains has thus far been spoken of as if it were a simple and pure porphyry. While the prevailing rock in the upper part of the mountain is the porphyry, this always contains irregular, angular fragments of other rocks, so that it is difficult to obtain a hand specimen that does not show one or more of these inclosed fragments. In places the rock fragments are so abundant as to make up the larger part of the ledge, constituting a breccia with the porphyry as the cement. Such a breccia may be seen on the south slope of Kearsarge at the 2,000 foot level, and continues to appear up to the 2,150 foot level. The fragments constituting the breccia vary in size from a fraction of an inch up to two feet or more in diameter. Those most frequently seen are of phyllite.

There is a large mass of this phyllite in the southern slope of Mount Kearsarge, which is crossed by the mountain trail at the 1,425 foot level. From this trail the phyllite area may be traced easterly and southeasterly to the first brook on the mountain side. The phyllite constitutes a mass in the south side of the mountain about one-fourth mile in length and 100 feet thick.

The phyllite is of a dark gray or slate color, of slightly greasy feel, and is very thinly laminated. The surfaces of the laminæ show a fine, delicate crinkling which is seen on a cross-section to be due to the beginning of a new structure almost at right angles to the lamination. The new structure is produced partly by a very fine faulting and partly by the compression of

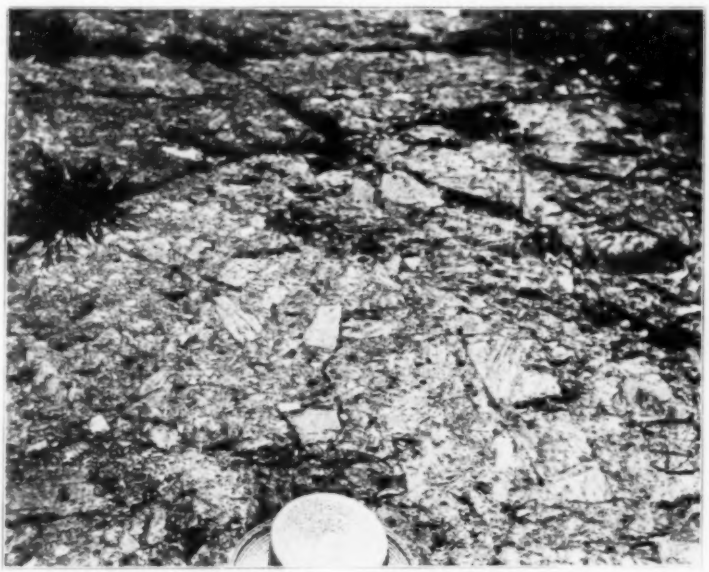

FIG. 2.— The breccia in Mt. Kearsarge — the surface of a ledge.

minute folds. There are beds of finely grained, light gray quartzite in the phyllite. They show that the present structure is parallel to the original bedding of the clay. There also appear on the laminæ minute dark spots, longer than wide, and pointed in shape, which are the beginnings of crystals, probably, of andalusite.

The phyllite mass has suffered extreme brecciation, being in large part a mass of simply indurated fragments. In part there is a peculiar regularity displayed in the brecciation. The breaking followed certain straight zones, only a few inches thick, within which the rock was shattered, and the fragments now

occupy every conceivable position, while the rock between, several feet in thickness, is not broken, is not even folded. Why the rock yielded so completely through these zones with so little disturbance to the intervening rock is difficult to understand. Near the border of the large phyllite mass the fragments separated somewhat, and the unsolidified porphyry flowed in and crystallized, making the border into a porphyry-breccia. Some of this is well exposed at the side of the trail on the south slope, and is shown in the illustration.

In addition to the phyllite, there are, inclosed in the quartz-porphyry, fragments of gray quartzite, of glassy quartz, and of quartz-porphyry. The quartz-porphyry in fragments closely resembles, frequently, the quartz-porphyry inclosing them.

In Moat mountain the quartz-porphyry contains a smaller number of fragments. Among these are those of glassy quartz, of rusty mica-schist, of quartz-mica-schist, of quartz-porphyry, of quartzite, of biotite-gneiss, of muscovite-granite, and of a dark gray, rusty rock, probably a basic eruptive. In addition to these small fragments, there is a large mass of phyllite, identical with the Kearsarge phyllite and completely brecciated, making up a large part of the top of Moat. The fragments of this breccia vary in size from those that are very small up to those a foot across. Some of these fragments contain andalusite crystals.

CONCLUSIONS.

1. The Conway granite, the granite-porphyry, and the quartz-porphyries, including probably those found in fragments, were formed by the solidification of a single magma.

The sedimentary rocks of this area, together with the underlying crystallines, were profoundly and thoroughly shattered, presumably by a disturbance associated with the coming of this magma into its present position.

2. The shattered condition of the phyllite affords a means of estimating the greatest depth at which this magma could have solidified. Included, as the shattered phyllite was in the molten magma, the latter was not at a depth greater than that of the zone of fracture for the phyllite.

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THE STOKES COLLECTION OF ANTARCTIC FOSSILS.

MR. F. W. STOKES, artist to the late Belgian Antarctic expedition, collected in February, 1902, a few specimens of fossils upon the Antarctic continent at Admiralty Inlet, Louis Philippe Land, south of South America. These fossils are the first which have ever been brought back by any of the expeditions to the far south, and great praise is due Mr. Stokes for affording this means of identification for the first time, of the age of sedimentary strata upon Antarctica. The collection is not large, containing scarcely more than a dozen specimens, but a sufficient number of species have been recognized to determine somewhat definitely the age of the strata containing them, and to permit of important conclusions as to the faunal geography of Upper Cretaceous time. In the study of the collection the writer is indebted to Dr. T. W. Stanton, of Washington, for valuable suggestions.

The specimens were all collected from a talus slope. Most of them occur in concretionary nodules of a very dense, fine-grained brown sandstone, but the two specimens of Hamites are from a coarser-grained glauconitic sandstone which is reddish in color upon its weathered surfaces. The most perfect specimens of *Tubulostium callosum* occur completely weathered out, but the same species also occurs in the brown sandstone nodules. The original stratigraphic position of all the specimens was probably approximately at the same horizon.

As might be expected, several of the species prove to be undescribed forms and are here described for the first time. The species recognized are as follows :

Lucina? townsendi White.
Lagena ? antarctica, n. sp.
Tubulostium callosum Stol.
Olcostephanus antarctica, n. sp.
Haploceras? sp. undet.
Hamites elatior Forbes?

Hamites, sp. undet.
Glyphaea stokesi, n. sp.

The presence of the ammonites at once marks the fauna as of Mesozoic age, and the presence of such uncoiled forms as Hamites stamps it at once as Cretaceous. In an examination of the fauna for the purpose of making a closer correlation and to determine the relationships of the fauna with the Cretaceous faunas of other portions of the earth, it is found that these relationships point in two directions. The three species, *Tubulostium callosum*, *Lagena? antarctica* and *Olcostephanus antarctica*, seem to connect the fauna with the Middle or Upper Cretaceous faunas of southern India. The first of these is a peculiar little gastropod which is specifically identical with one originally described from the Utatur formation of southern India. The second species, *Lagena? antarctica*, is most closely related to *L. secans* Stol. from the Ariyalur formation of the same region, and the third, *Olcostephanus antarctica*, most closely resembles *Ammonites madrasinus* Stol., also from the Ariyalur beds of India. In the correlation of these deposits in India, the Ariyalur formation has been referred to the Upper Cretaceous by the Indian geologists, while the Utatur beds are placed in the Middle Cretaceous. The weight of the evidence afforded by the antarctic fossils, therefore, leans about equally towards the correlation of the beds containing them with the Middle or with the Upper Cretaceous beds of India, which would naturally lead to giving them a place in about the middle of the series.

In addition to these three species which establish the relationship of the Antarctic fauna with that of southern India, there are two species, *Lucina? townsendi* and *Hamites elatior* which are identified with forms which have been described by White from islands in the Straits of Magellan, thus establishing the connection of the fauna with that of the continent of South America. The specimens of *Tubulostium callosum* also, are somewhat closely allied to a species described by Stanton[1] as *T. pupoides* from the Cretaceous beds of Patagonia.

The evidence afforded by the specimens in the Stokes collec-

[1] Rep. Princeton Univ. Exped. to Patagonia, Vol. IV, Pt. I, p. 30.

tion seems to establish the relationship of this Antarctic fauna with the Middle or Upper Cretaceous faunas of southern India on the one hand and on the other hand with the Cretaceous faunas of southern South America, and it is believed that the evidence is sufficient to demonstrate the existence of a shallow water connection between these three regions in later Cretaceous time, possibly by way of Australia.

DESCRIPTION OF SPECIES.

MOLLUSCA.

PELECYPODA.

Lucina? townsendi White. Plate I, Figs. 2–3.

1890. *Lucina? townsendi* White. *Proc. U. S. Nat. Mus.*, Vol. XIII, p. 14. Pl. III, Figs. 1–2.

Description.—Shell attaining a length of 70^{mm} in the larger of the two specimens in the collection, subovate in outline, moderately convex, the greatest convexity being one-fourth the total height of the shell below the beaks, the hinge-line arcuate, about two-thirds the total length of the shell. Anterior margin rounded in outline, passing imperceptibly into the more gently rounded ventral margin; posterior margin rather sharply rounded below and in the casts sinuate above. In the internal casts the postero-dorsal surface is rather abruptly depressed, this depression being bounded internally by a slight sinuous, rounded ridge. The adductor muscle impressions are subequal, of rather large size, the posterior ones included almost wholly within the depressed portion of the valve and its bounding ridge, the anterior ones just below the anterior extremity of the hinge-line. Surface markings of the exterior of the valves poorly preserved, apparently consisting of somewhat irregular growth lines only; the surface of the casts marked in the lower third of the valves by more or less irregular and rather obscure, flattened, radiating ribs which become obsolete before reaching the ventral margin.

The dimensions of the smaller and better preserved of the two specimens are: length, 43^{mm}; height, 38^{mm}; thickness through both valves, 22^{mm}. The dimensions of the larger example are: length, 70^{mm}; height, 56^{mm}; thickness through both valves, 42^{mm}.

—Walker Museum Pal. Coll. No. 9707–9708.

Remarks.—The generic reference of these shells cannot be made with certainty because the hinge-characters are not well preserved in either specimen. On the right valve of the smaller specimen, however, near the anterior extremity of the hinge-line, several processes are exhibited which seem to resemble the teeth of the genus Trigonarca. The species seems to be identical, however, with White's *Lucina? townsendi*, described from islands in the Straits of Magellan, and in the absence of any definite proof to the contrary his generic identification is allowed to stand.

GASTROPODA.

Lagena? antarctica, n. sp. Plate I, Figs. 4, 5.

Description.—Shell rather small, fusiform, with about four volutions, the periphery forming a sharp revolving keel. Spire elevated, its height but little less than that of the outer volution. From the revolving keel the surface of each volution slopes abruptly to the suture below, the upper surface of the volution has a much longer concave slope to the suture above. The outer slope of the last volution drops abruptly from the periphery, is then concave for a short distance and then continues in a nearly straight or slightly convex line to near the anterior extremity of the shell where it is again concave.

Surface of shell marked by fine lines of growth which bend backward in passing from the suture to the peripheral keel.

The dimensions of the only specimen observed are: total height 19.5 mm, diameter of last volution on the periphery 11 mm.

—Walker Museum, Pal. Coll. No. 9713.

Remarks.—This species is established upon a single specimen which preserves the mould of the exterior and a cast of the interior of the shell. It is a rather unusual form of gasteropod shell in Cretaceous faunas and agrees most closely with a species described as *L. secans* Stol., from the Upper Cretaceous of southern India. The antarctic species[1] here described may be distinguished from the Indian species by the absence of the angular revolving rib upon the outer volution below the peripheral keel. In other respects the two species are much alike.

Tubulostium callosum Stol. Plate I, Figs. 6–17.

1898. *Tubulostium callosum* Stoliczka. *Pal. Ind.*, "Cret. Faun. of S. Ind., Gasteropoda," p. 241. Pl. XVII, Figs. 26–32.

Description.—Shell sinistral, thick and rugose, more or less nearly discoidal in form, sometimes with a low spire, aperture circular, entire. Volutions exceedingly irregular, apparently three or four in number, the inner ones being eroded in all specimens observed so that their number, cannot be accurately determined. The peripheral portion of the shell is much thickened, the thickened portion being divided into three strong, more or less irregular revolving ribs; the shell is also marked by conspicuous, irregular lines of growth.

The dimensions of the best preserved specimen are: maximum diameter 17 mm, height of outer volution 8 mm, diameter of aperture 3 mm.

—Walker Museum Pal. Coll. No. 9711.

Remarks.—This little shell has been identified with a south Indian species although none of the Indian specimens which have been illustrated are as nearly discoid in form as some of the Antarctic ones. The Indian specimens, so far as illustrated at least, agree most closely with Fig. 17 upon the accompanying Plate I. The four specimens here illustrated show a regular gradation from the more discoid to the more heliciform shells, and without doubt all are members of a single species.

[1] *Pal. Ind.*, "Cret. Faun. of S. India Gasteropoda," p. 138, pl. 11, f. 20.

All of the Antarctic specimens are sinistral; in the original description the species is said to be usually sinistral, but some of the Indian specimens are dextrally coiled and in a larger collection from Antarctica both forms of shell would doubtless be discovered. The species is also somewhat closely allied to *T. pupoides* Stanton, from the Cretaceous beds of Patagonia.

CEPHALOPODA.

Olcostephanus antarctica, n. sp. Plate II, Figs. 1–2.

Description.—Shell discoid, compressed, dorsum regularly rounded, the aperture two-thirds as broad as high. Umbilicus of moderate size with nearly vertical sides, leaving about three-eighths of the inner whorls exposed. Surface of whorls marked by sharply elevated transverse ribs which are continuous uninterruptedly across the dorsum, their crests being from two to three millimeters apart; most of these ribs originate in a row of tubercles upon the edge of the umbilicus, each tubercle giving rise to two or three ribs, but between the ribs originating in this way there are others which start on the edge of the umbilicus between the bases of the tubercles. The crest of each rib is surmounted by a row of small, low, tubercles about two millimeters apart.

The maximum diameter of the type specimen is 68 mm, the height of the aperture 30 mm, and the width of the aperture 20 mm.

—Walker Museum Pall. Coll. No. 9706.

Remarks.—This type of Ammonite shell, with strong lateral ribs which usually originate in fascicles from nodes on the border of the umbilicus and continue uninterruptedly across the dorsum, is uncommon in the Cretaceous faunas of North America, where it is recognized only in beds of Neocomian or Lower Cretaceous age on the Pacific coast. In Europe the genus is restricted to the Upper Jurassic and Lower Cretaceous. The antarctic species here described, however, is not closely similar to any of the American or European species of the genus, but is allied to several species of Ammonites (*A. kaliki* Stoliczka, *A. madrasinus* Stoliczka, and *A. bhawani* Stoliczka),[1] from the Middle Cretaceous beds of Southern India, all of which should probably be referred to the genus Olcostephanus. *O. antarctica* may be distinguished from all of the Indian species, however, by the line of low tubercles which surmounts each one of the lateral ribs of the shell.

Haploceras? sp. undet. Plate II, Fig. 5.

A single distorted and imperfect specimen of a cephalopod with all the inner whorls destroyed, may be referred to the genus *Haploceras* with a query. The surface of the shell is smooth, the dorsum rounded, with the lateral surfaces gently convex and rounding rather abruptly into the umbilicus which is of moderate size. So far as can be determined the margin of the aperture is continuous, not being produced forward on the sides and on the dorsum, but the specimen is not in a condition to show the form of the aperture with certainty. None of the sutures are preserved.

[1] *Pal. Ind.*, "Foss. Ceph. of Cret. of S. India."

The dimensions of the specimen are: maximum diameter 34^{mm}, height of aperture 17^{mm}, width of aperture 14^{mm}.

—Walker Museum, Pal. Coll. No. 9712.

Hamites elatior Forbes? Plate II, Fig. 3.

1890. *Hamites elatior* Forbes? White, *Proc. U. S. Nat. Mus.*, Vol. XIII, p. 13. Pl. II, Figs. 1–2.

Two specimens in the collection may be referred provisionally to the genus Hamites. One of these is a fragmentary cast of the straight portion of an individual whose diameter must have been about 60^{mm}. On this specimen the annular ridges are closer together than on the other one, the intervals ranging from 3 to 4^{mm}, and on one side the annulations exhibit a shallow sinuosity. The specimen seems to possess all of the essential characters of *H. elatior* Forbes? as identified by White from the Straits of Magellan and is therefore so identified. — Walker Museum, Pal. Coll. No. 9709.

Hamites sp. undet. Plate II, Fig. 4.

The second specimen referred to Hamites is a portion of the impression of the exterior of a very large individual, which, judging from the curvature of the fragment at hand, must have had a diameter of 80^{mm} or more. It is a part of the straight portion of the shell with the crests of the annulations about 6.5^{mm} apart. The raised annular ridges are not symmetrical, the slope on one side being more abrupt than on the other.

—Walker Museum, Pal. Coll. No. 9710.

ARTHROPODA.

MALACOSTRACA.

Decapoda.

Glyphaea stokesi, n. sp. Plate I, Fig. 1.

Description.— Cephalothorax highest toward the front, somewhat flattened both dorsally and laterally, with a short, sharply pointed rostrum. Anterior margin sinuate between the rostrum and the base of the antennae, it rounds regularly into the gently convex ventral margin. From a little in front of the middle of the ventral margin of the lateral surface of the cephalothorax a a conspicuous rounded furrow is directed obliquely upward and backward, crossing the flattened dorsal surface transversely at about one-third of the total length of the cephalothorax from its posterior extremity; from the same point of origin at the ventral margin another furrow describes a sigmoidal curve first forward, then upward and nearly vertical, and then forward and nearly horizontal again, becoming less and less sharply defined to the anterior margin just above the base of the antennae; from this sigmoidal furrow there are two shorter and less well defined furrows directed obliquely downward and forward towards the antero-ventral margin. At the posterior extremity of the cephalothorax a transverse furrow extends across the dorsal surface close to and parallel with the margin. Between the two principal furrows upon the lateral surface of the cephalothorax, and just above their

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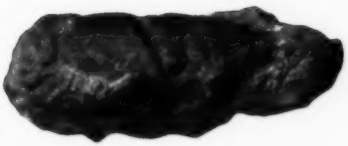

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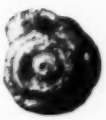

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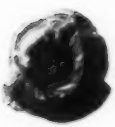

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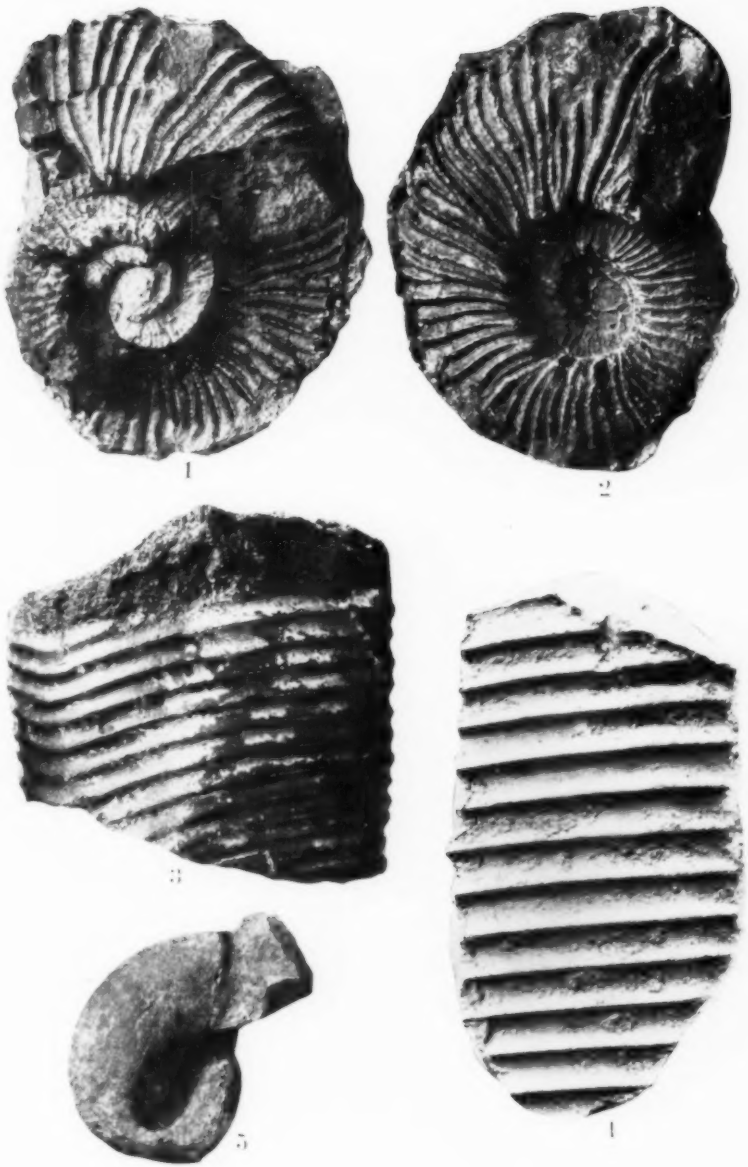

point of origin, there is a subcircular, depressed-convex, node-like elevation, and between the two shorter furrows which are directed obliquely downward and forward from the sigmoidal furrow is another similar subelliptical elevation. Just back of the base of the antennae is a rather sharp, keel-like ridge reaching backward to the first of the short oblique furrows. Back of the base of the rostrum, upon the dorsal side of the cephalothorax there are two small, sharply pointed tubercles upon each side of the median line; the anterior one is the larger and is situated almost directly in front of the smaller posterior one.

Abdomen consisting of six segments and a strong telson posteriorly, altogether being as long or longer than the cephalothorax.

The dimensions of the type specimen are: extreme length of cephalothorax 32^{mm}, greatest height 14^{mm}, length of rostrum 4^{mm}.

—Walker Museum, Pal. Coll. No. 9705.

Remarks.—This species is represented in the collection by a single specimen which exhibits in good condition one side of the cephalothorax up to the dorsal median line, with the segments of the abdomen and the telson attached but imperfectly preserved and recurved along the ventral side. Fragments of the legs and the basal joint of one of the antennae are also preserved but not in such a condition as to admit of description. The specimen represents a species which is quite distinct from any of those previously described from the Cretaceous.

EXPLANATION OF PLATES

PLATE I.

FIG. 1. *Glyphaea stokesi*, n. sp. Lateral view of the type specimen.

FIGS. 2–3. *Lucina? townsendi* White. 2. Laterial view of the right valve of a small specimen. 3. A larger, less perfect specimen believed to belong to the same species.

FIGS. 4–5. *Lagena? antarctica*, n. sp. 4. Lateral view of a wax cast taken from a natural mould of the exterior. 5. The natural cast of the interior of the shell.

FIGS. 6–17. *Tubulostium cullosum*. Stol. Three views each of four different specimens.

PLATE II.

FIGS. 1–2. *Olcostephanus antarctica*, n. sp. 1. Lateral view of the type specimen. In part an internal cast and in part an impression of the exterior. 2. Lateral view of a wax cast taken from the natural mould of the exterior. Same specimen as Fig. 1.

FIG. 3. *Hamites elatior* Forbes? Lateral view of an imperfect cast of the interior.

FIG. 4. *Hamites* sp. undet. Lateral view of a plaster cast taken from the natural mould of the exterior.

FIG. 5 *Haploceras?* sp. undet. Lateral view of the only specimen observed.

STUART WELLER.

Reviews

SUMMARY OF THE LITERATURE OF NORTH AMERICAN PLEISTOCENE GEOLOGY. 1901 AND 1902.

Frank Leverett.

In the two years covered by this summary there have been published in the neighborhood of 150 papers and reports (a few of which the reviewer has been unable to obtain), which either wholly or in part discuss features or problems of North American Pleistocene geology. About forty papers pertain to the Dominion of Canada, and half as many to Alaska and the Cordilleran part of the United States, while nearly every state which falls within the limits of glaciation has had notice in from one to fifteen papers. Iowa appears to lead the states in number of papers published, though New York is but little behind, and Massachusetts, Michigan, Indiana, and Wisconsin have a good showing. New Jersey has been favored by the appearance of a voluminous report on glacial geology, while Ohio and parts of neighboring states are embraced in a monograph by the United States Geological Survey dealing entirely with the glacial formations and drainage features. Kansas and Minnesota have had a little notoriety in connection with the question of glacial man. A large number of papers have been brief contributions to magazines or to the bulletins, transactions, and proceedings of scientific societies or academies which deal usually with a small territory or a single subject. The official reports published by the state, United States, and Canadian surveys which contain matter on Pleistocene geology also in most cases give a large share of attention to the geology of the older rock formations. In such cases this review is confined to the Pleistocene portion. Inasmuch as each area has to some extent problems of its own, it has seemed advisable to group the papers areally. There is also a group composed of papers of a general nature.

THE CORDILLERAN REGION IN CANADA.

Brock, R. W. *The Boundary Creek District, British Columbia.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 49–67, 1902.

The area examined was confined to the Grand Forks and Kettle River mining divisions of the boundary district. Glaciation is discussed mainly on p. 57. None of

the mountains are of sufficient altitude to support glaciers now, but glacial phenomena due to the Cordilleran ice-field are everywhere strikingly evident. The average direction of striation when uninfluenced by local causes is about S, 30° E. Drift "terraces" are numerous at all altitudes, up to 2,000 feet above the valleys. Since glaciation the surface oxidation and weathering has been very slight.

DALY, R. A. *Geology of the Region Adjoining the Western Part of the International Boundary.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 37–49, 1902.

The area discussed embraces a tract eighty miles from west to east and ten miles in width on the north side of the international boundary from the Gulf of Georgia eastward. The glacial geology is mainly treated on pp. 41–5, and embraces a brief discussion of glacial erosion and denudation, cirques, mountain tarns, and small lakes, river terraces, and deltas. A morainal dam which holds in Chilliwack lake is also described. This lake stands 1,850 feet above the sea, and the granite walls rise steeply 3,000 to 4,500 feet higher, with truncated spurs between tributary gulches that indicate a large amount of glacial erosion.

GWILLIM, J. C. *Glaciation in the Atlin District, British Columbia.* Jour. Geol., Vol. X, pp. 182–5, 1902.

The great valleys of northern British Columbia show evidence of glacial action which occurred after the valleys had reached about their present dimensions. There appears to have been regional glaciation followed by a partial or local glaciation. There is also a present active glaciation in coast ranges to the westward. The regional glaciation left its marks on the slopes up to an altitude 5,000 feet above the valleys, and the movement was northward. The local glaciation was restricted to the upper valleys and slopes, but did not cover the high parts of mountains.

The paper closes with a brief description of the Llewellyn glacier near Atlin lake. The upper surface of the ice-field is about 5,000 feet above sea level or 3,000 feet above Atlin lake.

MCCONNELL, R. G. *The Yukon District.* Geol. Surv. Canada, Summary Rept. for 1901, pp. 23–37, 1902.

Results of examinations at several of the smaller placer camps in the Yukon district are presented. Livingston creek valley shows evidence of glacial action in its upper part and heads in a steep amphitheater. In most of the creek valleys the terraces and terrace material are reported to consist of ordinary stream wash, and no mention is made of glacial action.

PARKINSON, J. *Some Lake Basins in Alberta and British Columbia.* Geol. Mag., Decade 4, Vol. VIII, pp. 97–101, 1901.

Lake Agnes in the Canadian Rocky mountains is found to be in a rock basin. Mirror lake, into which it discharges, is not so clearly a rock basin. Lake Louise, farther down the valley, probably receives the discharge from Mirror lake by underground channels. Whether Lake Louise is a rock basin is not certain. Lake Marion in the Selkirk range is another case in which the evidence is not clear as to its being a rock basin. Among the agencies which may have been operative in producing the Lake Agnes rock basin, warping, glacier erosion, and decay of soft rocks in the upper end of the basin should be considered. The soft rocks might have been removed either by stream or glacier action.

VAUX, GEORGE, and WILLIAM, S., Jr. *Observations Made in 1900 on Glaciers in British Columbia.* Proc. Phil. Acad. Nat. Sci., for 1901, pp. 213–15.

Notes on the movements of the glaciers are presented.

ALASKA.

BROOKS, A. H., and COLLIER, A. J. *Glacial Phenomena of the Seward Peninsula.* Abstract, Science, N. S., Vol. XIII, 1901, pp. 188, 189.

No evidence of general glaciation was found, but there were centers of local glaciation. The valleys of the Kiglow-aik range are glaciated to 500 feet above the valley floors, and the moraines were deposited close to tide water. Shrunken remnants of some of the glaciers still persist, and are, so far as known, the most northerly in Alaska, being in latitude 65°. There is evidence of a recent elevation of 600 to 800 feet, but it antedates the maximum extension of the glaciers.

BROOKS, A. H. *Sketch of the Geology of Southeastern Alaska.* Professional Paper No. 1, U. S. Geol. Surv., pp. 31–3, 1902.

Existing glaciers are found chiefly on the Pacific mountain system, and the largest development is on the seaward slope. On the Pacific side of the St. Elias range the perpetual snow limit is about 2,000 feet, and on the inland slope about 6,500 feet. The glaciers on the Pacific slope are much larger than on the inland slope. The Coast Range has less conspicuous glaciers than the St. Elias, and they are mainly on the seaward slope.

The extent of former glaciation was much greater than at present, though its limits were fully determined at but few points. It is not known whether the higher mountains were covered. On Prince of Wales Island glacial action was found up to 2,200 feet, but near Niblack Anchorage it seems to have reached no higher than 2,000 feet. In general the Alexander Archipelago was glaciated up to at least 2,000 feet. Farther north glaciation reached higher altitudes, there being glacial bowlders near Juneau at 3,200 feet, and this town stands on a moraine. Terraces along the valley walls of Chilcat and one of its tributaries are thought to have been built while the valley was still occupied by glacier ice. Rock-cut basins occupied by lakes are not uncommon, especially in the Ketchikan region. On Prince of Wales Island is a lake basin a mile long and a quarter of a mile broad entirely surrounded by a rock rim.

BROOKS, A. H., RICHARDSON, G. B., COLLIER, A. J., and MENDENHALL, W. C. *Reconnaissances in the Cape Nome and Norton Bay Regions, Alaska, in 1900.* House Doc., No. 547, 56th Cong., 2d Sess., 222 pages, 1901.

The surface geology is briefly discussed on pp. 41–7 under the topics: river and stream gravels, beach deposits, terrace deposits, glacial deposits, extra-morainic drift, ground ice, and soil. No evidence of regional glaciation was found, but four local centers of glacial action are reported. Of these the most important is in the Kiglu-aik mountains. There the valley slopes are glaciated up to an elevation 500 to 600 feet and head in glacial cirques, while at the margin typical moraines were found. Remnants of glaciers still persist in the higher mountain valleys. The extra-morainic drift found in the vicinity of Nome reaches an altitude of 800 feet. It is not necessarily

glacial, but may have been brought by ice-floes at a time when the land stood about 800 feet lower than now. A subsidence of that amount would greatly change the contours of the coast and make islands of part of the mainland.

The Norton Bay region has suffered no general glaciation, but may have carried small local glaciers.

COLLIER, A. J. *Reconnaissance of the Northwestern Portion of the Seward Peninsula, Alaska.* Professional Paper No. 2, U. S. Geol. Surv. 68 pages, 1902.

Surface deposits are discussed on pp. 24–9. Aside from the sand and gravel along the coastal plain and the streams, there are a few places where rounded pebbles and washed gravel occur at high altitudes remote from streams. There has been but little glaciation in the mountains of this region.

Evidences of uplift and warping are discussed on pp. 34–43. The plateaus, benches, and plains indicate four extensive cycles of uplift and erosion, all of which are post-Mesozoic.

GANNETT, HENRY. *General Geography of Alaska.* Harriman Alaska Expedition, pp. 257–77, 1901; also Nat. Geog. Mag., Vol. XII, pp. 180–96, 1901.

Attention is called to the fact that nowhere else on the earth is such magnificence of mountain fiord and glacier scenery to be found. It is thought that glaciation has been a very important factor in shaping the fiords and rounding the mountain surfaces. The present glaciers, though far larger than those of Switzerland, are trifling compared to their predecessors. There is a narrow strip of low coast from the Mount. St. Elias region westward, and the Alaskan coast of Bering sea is mainly low and marshy. The Yukon delta covers thousands of square miles. The Yukon river is navigable for small steamers throughout its course in Alaska. The interior of Alaska is but little known, but so far as explored is found to be traversed by a system of rivers navigable for canoes, though in some cases interrupted by rapids and low falls. The Pacific coast climate is very damp and the skies are cloudy. It is much warmer than the coast of Bering sea, because the latter is practically a closed sea to which the warm waters of the Pacific do not have access. The interior is subjeet to a far greater range in temperature than the coast, there being a known range of about 150° Fahrenheit in certain localities along the Yukon.

MUIR, JOHN. *The Pacific Coast Glaciers.* Harriman Alaska Expedition, Vol. I, pp. 119–35, 1901.

The Sierra Nevada of California carry sixty-five small glaciers at altitudes of 11,000 to 12,000 feet. They are mainly between latitude 37° and 38°. On Mount Shasta a glacier extends down to 9,000 feet. The Cascade range of Oregon and Washington has groups of glaciers on the highest mountains. From Mount Ranier they descend to 3,000 to 4,000 feet above the sea.

In British Columbia and southeastern Alaska the broad lofty mountains along the coast are usually laden with ice, and the upper branches of nearly all the canyons occupied by glaciers. The highest and snowiest are between latitude 56° and 61°, and they afford a considerable number that discharge icebergs into the sea. This very snowy field is about 500 miles long and 100 miles broad, and probably includes

nine-tenths of the ice on the coast. Glaciers are very few and small north of latitude 65°.

There are about 100 large glaciers that do not reach the sea. The Malaspina is the largest, being about 20 miles by 65 or 70. Many are 2 to 4 miles wide. Of glaciers that flow out into the sea the author has seen twenty-eight, and knows of at least three more, while several fiords in Prince William sound remain unexplored. The southernmost is Leconte glacier in latitude 56° 50′. Three reach the sea in Taku Inlet and nine in Glacier bay. Of the last named the largest is the Muir glacier, which is twenty-five miles wide below the junction of the main tributaries, while the area of its basin is scarcely less than 1,000 square miles.

Glaciated surfaces testify to a grand continuous ice-sheet that not long ago fringed this coast along all the island region as far south as the strait of Juan de Fuca. Traces of former glaciation are also found farther north than the present limits, especially on the fiords below mountain ranges. Muir in 1881 noted evidences of glaciation in Plover bay on the Siberian coast.

SCHRADER, F. C., AND SPENCER, A. C. *Geology and Mineral Resources of a Portion of the Copper River District, Alaska.* House Doc. No. 546, 56th Cong., 2d Sess., 94 pages, 1901.

The Pleistocene deposits, physiography, and glaciation are discussed on pp. 58–82. There are heavy deposits of till and other glacial material in the Copper river basin, and the rounded topography of a glaciated region at higher altitudes. The deposits appear to have been formed by a glacier that had its source in the Wrangell mountains and adjacent Alaska range. Streams have cut to a depth of several hundred feet, and have not yet reached the level of the old rock floor.

In Prince William sound the evidence of glaciation extends to the water's edge along the mainland, for the shore is striated. Several of the islands also contain glacial material brought from the mainland. It is thought probable that the topography of the sound has been greatly affected by glacial erosion.

THE CORDILLERAN REGION OF THE UNITED STATES.

ARNOLD, RALPH. *The Pleistocene Geology of Southern California.* Abstract Science, N. S., Vol. XV, pp. 415, 416.

A summary statement of the marine Pleistocene of southern California with the subdivisions of Pleistocene formations.

ARNOLD, DELOS, and ARNOLD, RALPH. *The Marine Pliocene, and Pleistocene Stratigraphy of the Coast of Southern California.* Jour. Geol., Vol. X, pp. 117–38, 1902.

The faunas indicate a fluctuation of conditions along the California coast from the beginning of Pliocene times. Southern or warm conditions prevailed in the early Pliocene, northern or boreal in the late Pliocene and early Pleistocene, and warm conditions again in the remaining or greater part of the Pleistocene.

DILLER, J. S. *Glaciation of Mount Mazama.* Professional Paper No. 3, U. S. Geol. Survey, pp. 41–4, 1902.

This paper, which discusses the geology of the Crater Lake National Park, contains a brief discussion of the glaciation. Mount Mazama was a volcanic cone which

apparently collapsed as a result of the withdrawal of the liquid interior of the cone at a time subsequent to the glaciation. By this ingulfment seventeen cubic miles of material is thought to have disappeared. A correlative effusion at some other point is likely to have occurred, but it has not yet been located.

This mountain, which once occupied the position of Crater lake, had glaciers whose deposits and striæ are to be found on the rim of the crater and the mountain slope outside, but not on the slope toward the lake. On the lower slope of the mountain were tongues of glacier ice occupying the valleys only, but at the level of the rim (about 8,000 feet A. T.) nearly all the surface was glaciated. Ground moraine material is widespread, and a few terminal moraines occur. Mention is made of one which is 200 feet in height. Canyon-cutting by glaciers is also a marked feature.

FAIRBANKS, H. W. *Lake Chelan, Washington.* Abstract Science, N. S., Vol. XV, pp. 412, 413, 1902.

The Lake Chelan valley was occupied in recent times by one of the largest glaciers on the eastern slope of the Cascade range. Previous to that there was another lake in the valley at a somewhat lower level, which must have emptied into the Columbia river. The author holds that the great depth of the lake is due, not to the erosion by the glacier, but to stream erosion, and this erosion must have occurred prior to the formation of the Columbia lava plateau. A morainal dam holds the lake to its present level of 325 feet above the Columbia river. The author knows no reason to suspect that bed-rock will be encountered above the level of the Columbia river.

FAIRBANKS, H. W. *Pyramid Lake, Nevada.* Pop. Sci. Monthly, March, 1901.

A popular discussion of the features of this lake and of the history involved in the greater Lake Lahontan which once covered this site.

FENNEMAN, N. M. *The Arapahoe Glacier in 1902.* Jour. Geol., Vol. X, pp. 839–51, 1902.

A glacier formerly nine miles long is now reduced to a mile in length and occupies a cirque opening eastward to North Boulder creek in Colorado. Deficiency of snow the past three winters and excessive melting in the summers give exceptional opportunity for study and bring out features not known before. The glacier is really much branched, because of inequalities of the rock-bed, and has interesting moraines and crevasses and a prominent *bergschrund* at the line between the névé and the glacier proper. There is evidence of an uplift, but it is thought to have long antedated the glaciation.

GANNETT, HENRY. *Origin of Yosmite Valley.* Nat. Geog. Mag., Vol. XII, pp. 86, 87, 1901.

This paper was called out by the appearance of a paper by H. W. Turner on the origin of the Yosemite valley,[1] in which the potency of a glacier for the work of erosion is denied. Gannett thinks that the gorges in the high Sierra were cut by glaciers and holds the view that the line of demarkation between the channels made by the ice, and the valleys made by the streams, can be determined almost to a foot.

[1] "The Pleistocene Geology of the South-Central Sierra Nevada, with a Special Reference to the Origin of the Yosemite Valley," *Proc. Calif. Acad. Sci.*, Vol. I.

HERSHEY, OSCAR H. *The Quaternary of Southern California.* Bull. Dept. Geol. Univ. Calif., Vol. III, pp. 1–30, 1902.

The paper discusses the orographic disturbances in the early part of the Quaternary which lifted upper Pliocene beds to altitudes several thousand feet above the sea. A provisional scheme of classification is then brought out, which is expressed in the table below. The last column represents mere suspicions as to relative lengths of the different epochs.

TABLE OF QUATERNARY CONDITIONS.

	Recent Period	Modern Epoch		Deposition	Land-Level Below Normal	Length Ratio 5
Quaternary Era	Pleistocene Period	Le Conte's Sierran Period	Glacial Epoch	*Not represented*	*Not known*	5
			Not named	Erosion	Normal	10
			San Pedran Epoch	Deposition	Below normal	5
			Los Angelan Epoch	Erosion	Normal	75
			Red Bluff Epoch	Deposition	Below normal	10
			Santa Claran Epoch	Erosion	Normal	890

HERSHEY, OSCAR H. *The Term Sierran.* Am. Geol., Vol. XXIX, pp. 88–95, 1902.

It is considered doubtful if the contemporaneity of uplift on the Pacific coast with that in the eastern part of the United States has evidence to amount to a demonstration. For this reason it seems premature to attempt to correlate erosion cycles on opposite sides of the continent. The Sierran valleys cannot be directly compared with the Ozarkian valleys of the Mississippi basin. It appears highly probable that the Sierran excavation on the Pacific coast began before the opening of the Glacial epoch of the eastern states and was contemporaneous in part with the Ozarkian. But it is still in progress and was only slightly affected by glaciation in the high Sierra Under LeConte's definition Sierran covers, apparently at least, part of the Ozarkian and nearly all of the Glacial epoch. The so-called Glacial epoch of the California mountains was probably one-twentieth or one-fiftieth of the Glacial epoch of the eastern part of the United States. The author does not attempt to use "Ozarkian" on the Pacific coast, nor "Sierran" in the interior of the United States.

HILGARD, E. W. *The Débris Fans of the Arid Regions in their Relation to Water Supply.* Abstract, Science, N. S., Vol. XV, p. 414, 1902.

The structure of the débris fans is described and the value of these fans in forming natural storage and regulating reservoirs for water is brought out.

HILGARD, E. W. *A Sketch of the Pedalogical Geology of California.* Abstract, Jour. Geol., Vol. IX, pp. 74, 75, 1901; also Bull. Geol. Soc. Amer., Vol. XII, pp. 499–500, 1901.

The paper discusses the soil conditions, including also the difference between rock decomposition in arid and humid climates. In the humid regions loams and clay soils are produced, while in arid regions the soils are sandy and dusty unless derived from pre-existing clay formations which give rise to "adobe." In the arid regions there is a uniform soil mass to a depth of four to ten feet, with practically no subsoil,

and these soils almost universally contain high percentages of lime and potash, because not subject to the leaching process which affects the soils of the humid regions.

RITTER, WILLIAM E. *Subsidence of Santa Catalina Island in Recent Geological Times.* Science, N. S., Vol. XIV, pp. 575–7, 1901.

A submerged cobblestone beach three quarters of a mile to a mile out to sea from the present shore is cited in proof of the subsidence.

SALISBURY, R. D. *Glacial Work in the Western Mountains in 1901.* Jour. Geol., Vol. IX, pp. 718–31, 1901.

Reports results of investigations by several parties in northwestern Montana both east and west of the Rocky mountains; in the mountains of New Mexico, and in the Wasatch mountains.

The work east of the Rockies in Montana determined the limits of the northeastern ice-sheet and developed evidence concerning moraines of fourteen glaciers from the Rocky mountains. The work west of the Rockies was largely given to mapping the moraines of glaciers which extended southward in the lowlands and valleys.

In the Wasatch the positions of fifty Pleistocene glaciers exceeding one mile in length were determined, as well as traces of smaller glaciers and more than a dozen névé fields. Several of the glaciers reached the shore of Lake Bonneville, and the moraines of at least three of them are partially buried by the fluviatile deposits near the shore or possibly by the shore deposits. The altitude necessary to give rise to a glacier in that region was 8,000 to 9,000 feet. The glaciers were more numerous and larger, and the glaciation more vigorous, on the western slope than on the eastern, because of larger catchment basins and heavier snowfall. These mountains afford evidence of two widely separated episodes of glaciation.

In the New Mexico Rockies an altitude of 11,700 to 12,000 feet was necessary to produce glaciation. At least no evidence was found on peaks of lower altitude, though the search was not exhaustive. The longest glacier track is seven miles, and extends down to 9,200 feet.

It was also discovered that the Spanish Peaks of Colorado were once glaciated on their northern slopes.

STONE, G. H. *Note on the Extinct Glaciers of New Mexico and Arizona.* Science, N. S., Vol. XIV, p. 798, 1901.

The former occurrence of glaciers on the La Plata and San Juan mountains of southwestern Colorado is referred to, an account of which had previously been published. The Conejos range of the San Juan in New Mexico was glaciated for only thirty to fifty miles south of the Colorado-New Mexico line. The Sangre de Christo range both in Colorado and New Mexico was glaciated, and glaciation extended nearly to Santa Fé. The farthest southwest that evidences of glaciation were found in Arizona is near Prescott. The névé of this glacier scarcely rose above 9,000 feet. The occurrence of glaciation so far south (latitude 34° 30′) was probably due to great snowfall owing to proximity to the ocean. It is suggested that glaciers may have existed on the lofty Mogallon mountains of New Mexico and Arizona which had not been examined.

TURNER, H. W. *A Post-Tertiary Elevation of the Sierra Nevada.* Abstract, Science, N. S. Vol. XV, pp. 414, 415, 1902.

A comparison is made of the grades of the Tuolomne river in Neocene times and the present, showing a grade of 142 feet to the mile for the Neocene, in the 33 miles above the mouth of Piute creek and 92 feet to the mile for the present channel. The Neocene stream flowed in a broad channel making deposits, which indicate comparatively gentle grades, though they are scarcely so marked on this river as on streams farther north. It is thought that the grade was at least as low as that of the modern stream, so that the present grade of the Neocene channel is much greater than the grade at the time it was occupied by the stream, and this must have been brought about by a differential uplift on the east.

Princeton Patagonian Reports. Vol. I. Narrative and Geography. By J. B. HATCHER. Published by the University, 1903; pp. 314; pls. L.

NO BETTER augury could be desired for the success of the Princeton Patagonian Reports, the publication of which has been eagerly awaited, than is furnished by this, the initial volume of the series. Although entitled "Narrative and Geography," this handsome volume contains much more than the mere record or field-notes of an explorer's itinerary, being as a matter of fact replete with all manner of observations on the natural history, geology and physiography of the region visited. A Nansen, a Stanley, in fact no one short of a trained naturalist could have produced such a work, which is of the order one might expect from a Humboldt or Darwin. Without doubt the present contribution ranks as one of the most noteworthy that has yet appeared concerning the physical and biological features of the lower extremity of the South American continent.

One cannot review this work of Mr. Hatcher without appreciating the justice of Professor Scott's tribute, who remarks in the editorial preface that, "the whole forms a monument of energy and skill which it is difficult to characterize without using terms which savor of exaggeration." Three large monographs dealing with the rich palæontological material brought back from South America are promised by Professor Scott, and he further states in regard to Mr. Hatcher's stratigraphic determinations, that they were "most useful, making possible for the first time a rational account of the geology of large areas in southern Patagonia." It deserves also to be remembered, in judging of the extent of these achievements, that an elaborate volume by Drs. A. Ortmann and T. W. Stanton on the invertebrate material has already made its appearance.

Besides having had the good fortune to secure tons of highly interesting palæontological material, Mr. Hatcher has placed geologists the world over in his debt by having definitely settled the problem as to the age of the Santa Cruz beds, which has long been a serious stumbling-block. Not only this, but he was able to trace the entire stratigraphic succession from the Cretaceous upward, thus furnishing us with a complete section of Patagonian formations. Doubts as to the occurrence of certain strata in particular areas have been satisfactorily cleared, and in a word, light has been shed upon a number of burning issues in geology and palæontology. The author also has much to say in his narrative of interest to the meteorologist and anthropologist. Climatal conditions, the character of the soil and its vegetation, very full accounts of the native Indians, their customs and peculiarities, and a great deal regarding the habits of wild animals, even the psychological experiences of himself and companions whilst buried in the wilderness — all these and many other topics are presented in a simple aud pleasing style; and what with the narrative and camera illustrations, the reader has a sense of being fairly transported into the heart of Patagonia.

With characteristic modesty, the author touches but lightly upon the hardships and privations endured by himself and faithful companions; yet we know that the party had only the most meager facilities and very limited means at its command, and we can only picture to ourselves in imagination how extremely serious the situation was at times, how apparently insurmountable the difficulties. No one can fail to admire the quiet courage, patience and energy of the man who planned and successfully carried out, almost single-handed, an expedition of such magnitude and so rich in scientific results, and at the same time in the face of such discouraging obstacles.

C. R. E.

NOTE TO THE ARTICLE ON "FORAMINIFERAL OOZE IN THE COAL-MEASURES OF IOWA.[1]

SINCE the publication of my article on "Foraminiferal Ooze in the Coal-measures of Iowa," which appeared in the preceding number of the JOURNAL, I have found, while at work on the University of Texas Mineral Survey, another bed of minute foraminifera in the Upper Carboniferous of Texas, on the east foothills of the Chinati mountains. The Upper Carboniferous has a thickness here of probably more than 3,000 feet, and the upper member consists of a series of limestones, several hundreds of feet in thickness, evidently equivalent to "the upper or white limestone" described by Tarr in his "Reconnaissance of the Guadalupe mountains" (*Geol. Surv. of Texas, Bull. No. 3*, p. 29). The small foraminifera are also here associated with *Fusulina cylindrica*, and occur most frequently in the lower 200 feet of this limestone.

J. A. UDDEN.

SHAFTER, TEX.,
May 9, 1903.

[1] JOUR. GEOL., No. 3 (April-May, 1903), p. 283.